

Software Development and Construction of Log Periodic Dipole Antenna Using MATLAB

Vijay S. Kale¹, Dnyandev B. Patil²

Associate Professor, Department of Electronic Science, KTHM College, Nashik, Maharashtra, India¹

M. Phil. student, Department of Electronic Science, KTHM College, Nashik, Maharashtra, India²

Abstract: Technological advantages in solar activities particularly in solar radio burst (type I, II, III, IV, V) in radio region have created a demand of designing and constructing of Log Periodic Dipole Antenna (LPDA) to monitor. LPDA also plays an important role in modern communication systems such as TV, radar etc. The lengths and spacing of the elements of a LPDA are increases logarithmically from one end to the other. This paper presents the types of LPDA, mathematical equations required to design, flow-chart, MATLAB (MATRIX LABORATORY) code to obtain the antenna parameters and structure dimensions of the antenna elements to construct and the details of constructed LPDA of frequency range of 160MHz to 1900MHz with 24 elements. MATLAB tools and built-in math functions enables to explore multiple approaches and reach a solution faster than traditional programming languages, such as C/C++ or Java. It provides a good accuracy to calculate LPDA structure parameters required for LPDA design.

Keywords: LPDA, MATLAB, Flow-chart, Program, e-CALLISTO, Solar burst.

I. INTRODUCTION

The solar radio burst has made a great progress in more than a decade. The ground observations are one of the most significant for space weather issue. To collect data, antenna is used to transmit or receive electromagnetic waves. The propagation in both cases is the same due to the principle of reciprocity. The log periodic dipole array antenna (LPDA) has attracted much attention because of the broadband frequencies and more sensitivity to detect signal of the Sun and also it is economical and practical to implement.

In 1960, Isbell [1] first introduced the broad band LPDA in free space. It has an end-fire radiation pattern which is needed for more applications [2, 3], Carrel [2] proposed standard approach for the design of the traditional LPDA antennas. A traditional LPDA antenna with wire dipole elements can achieve wide bandwidth of 10:1 and high gain of 10dB. The log periodic term is derived because of the uniform spacing between the resonant frequencies of antennas in a log periodic scale.

The bandwidth of such an antenna depends on the precision in manufacturing the smallest element in the array and the size of the largest element in the array [4]. It is a frequency independent. Log periodic dipole array antenna consists of an array of linear dipoles known as driven elements, each of different length and spacing between them. They has geometries that is specified by angles. These antennas are primarily used in the 10 MHz – 10 GHz region in a variety of practical applications such as Television, point-to-point communication, feeds for reflectors and lenses, etc.[5].

There are different types of LPDA. Frequency independent split beam antenna is a logarithmically periodic antenna provides a split beam having sensitivity to well-defined null condition that makes it useful in direction finding applications. Log-periodic zig-zag antenna is a log periodic dipole type antenna. It is having a

unidirectional radiation pattern and a relatively constant impedance level which is substantially independent of frequency over a wide bandwidth. Such an antenna is especially advantageous for minimizing signal losses in the commercial television frequency range. Log-periodic monopole antenna is a vertically-polarized log-periodic monopole antenna that comprises two closely spaced arrays of elements over a ground plane and connected to a balanced feed source. The arrays are separately excited out of phase by the source. Elements are in the shapes of trapezoidal, pseudo-trapezoidal and triangular. Twin zig zag log periodic antenna is identical conductive zig-zag structures, lies side-by-side in close proximity to each other in substantially the same plane of a planar dielectric board. Printed circuit LPDA includes dipole elements with arms having reduced size through use of high effective permittivity substrate portions. The radiation efficiency degradation generally associated with the use of a high permittivity substrate [6].

There are three important parameters while designing criss-cross LPDA antenna- scale factor (τ) that specifies the relative lengths and spacing factor (σ) that specifies the relative spacing of the antenna elements and the apex angle (α). As we know, LPDA is frequency independent, the electrical properties such as the mean resistance level R_0 , characteristic impedance of the feed line Z_0 and driving-point admittance Y_0 vary periodically with the logarithm of the frequency. It is the basic of the range of frequency due to number of elements. As the frequency f_1 is shifted to another frequency f_2 within the pass band of the antenna, the relationship is;

$$f_2 = f_1 / \tau \text{ where, } \tau \text{ is a design parameter } (\tau < 1.0) \text{ [4].}$$

The parameter α , is one-half the apex angle and is derived from τ and σ . Typical designs of LPDA have apex half angles of $10^\circ \leq \alpha \leq 45^\circ$ and $0.7 \leq \tau \leq 0.95$ [4]. To compute such parameter design uses different methods that consist

of complicated mathematical formulae. All design parameters are needed to calculate accurately to achieve accuracy of design and to improve the performance of the antenna. This paper mentions the mathematical steps, flow-chart and the MATLAB program. The MATLAB software is developed to design LPDA for for Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO). LPDA antenna is constructed for frequency range of 160MHz to 1900MHz with 24 elements. MATLAB is developed by Math Works INC. U.S. [7]. It is a high-level language and interactive environment for numerical computation, visualization, and programming. Its built-in math functions enable to explore multiple approaches and reach a solution faster than traditional programming languages, such as C/C++ or Java. It consists of GUI that helps in designing and Simulink to design time varying system, simulate design and graphical windows for plotting 2D or 3D graphs [8].

II. FORMULAE USED IN DESIGN

Geometric constant τ :

$$\tau = \frac{f_2}{f_1} \quad \text{Where, } f_2 > f_1 \quad (1)$$

Spacing factor σ :

$$\sigma = \frac{R_{n+1} - R_n}{2l_{n+1}} \quad (2)$$

Half apex angle:

$$\alpha = \tan^{-1} \left[\frac{1 - \tau}{4\sigma} \right] \quad (3)$$

Band-width of active region:

$$B_{ar} = 1.1 + 7.7(1 - \tau)^2 \cot \alpha \quad (4)$$

Required band-width:

$$B = \frac{F_{max}}{F_{min}} \\ B_s = B \times B_{ar} \\ B_s = B \times Bar \\ B_s = B [1.1 + 7.7 (1 - \tau) 2 \cot \alpha] \quad (5)$$

Where,

B_s = designed bandwidth

B = desired bandwidth

Bar = active region bandwidth.

Length of the structure:

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

Where,

$$\lambda_{max} = \frac{v}{F_{min}}$$

Virtual apex length V_{apex} :

$$V_{apex} = \frac{\left(2 \times \left(\frac{\lambda_{max} \times 3.2805}{2} \right) \sigma \right)}{\tau} \quad \dots \text{In feet.} \quad (7)$$

Number of element:

$$N = 1 + \frac{\ln(B_s)}{\ln\left(\frac{1}{\tau}\right)} \quad (8)$$

Characteristic impedance Z_a :

$$Z_a = 120 \left[\ln\left(\frac{l_n}{d_n}\right) - 2.25 \right] \quad (9)$$

Where,

$\frac{l_n}{d_n}$ is the length-to-diameter ratio of the n th element.

Mean radiation resistance of input impedance:

$$R_0 = \frac{Z_0}{\sqrt{1 + \frac{Z_0}{4\sigma'Z_a}}}$$

Centre to centre spacing of feeder line:

$$S = d \times \cosh\left(\frac{Z_0}{120}\right) \quad (10)$$

Where,

d is diameter of dipole in inch.

Z_0 is characteristic impedance

Relative mean spacing, σ'

$$\sigma' = \frac{\sigma}{\sqrt{\tau}} \quad (11)$$

Optimized values for σ can be obtained using fig.1 [4].

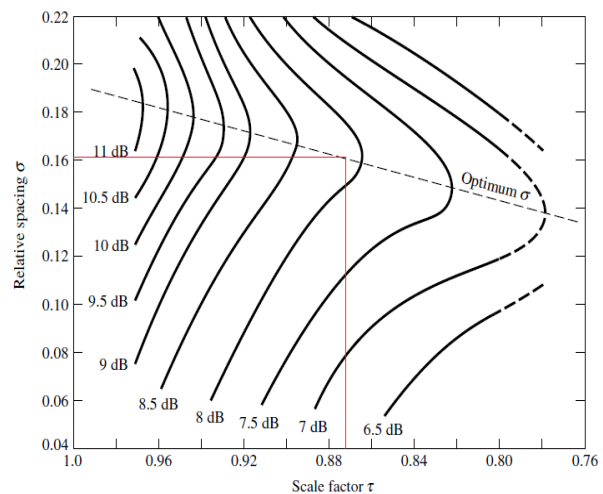


Fig.1. Computed Contours of constant directivity versus σ and τ .

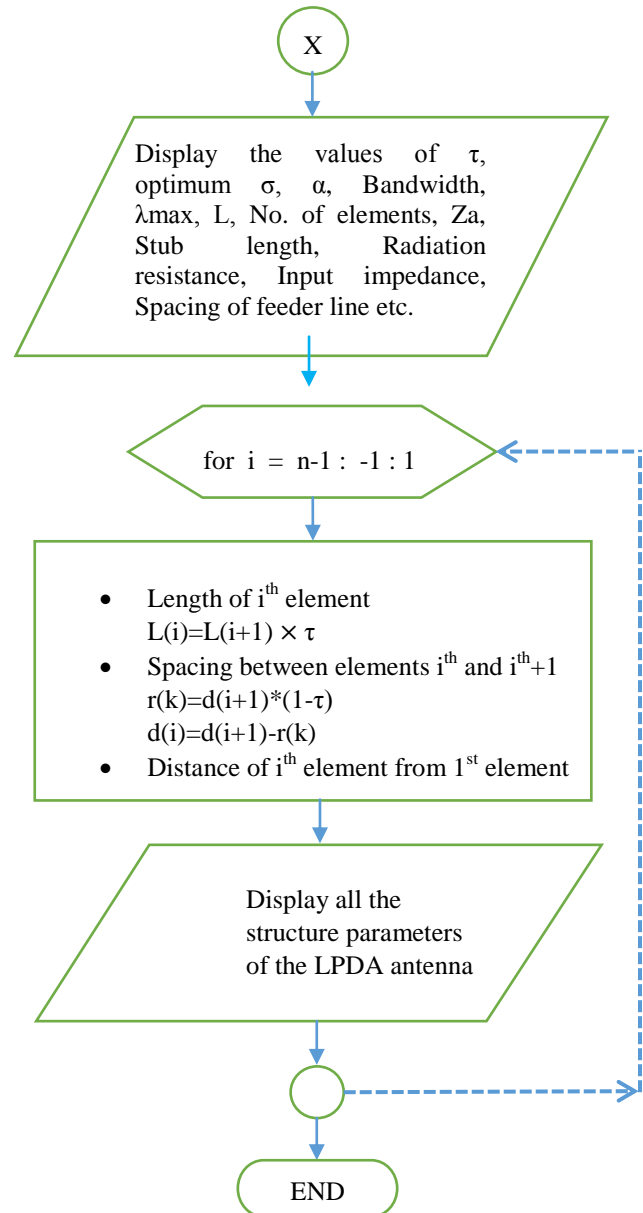
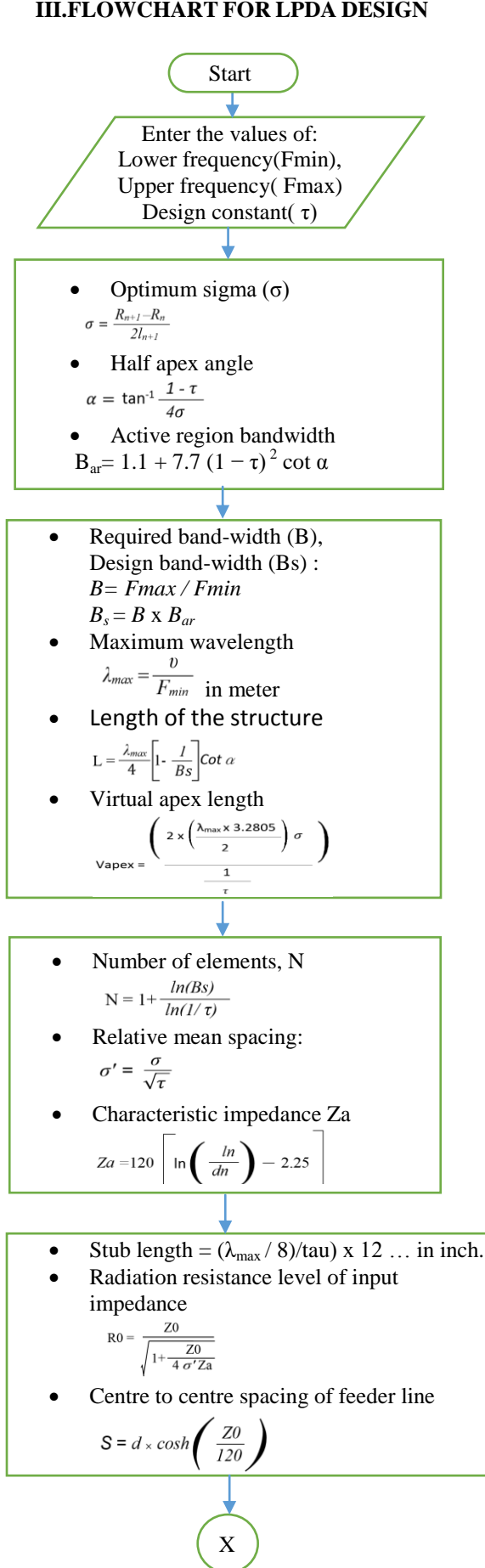
Stub length:

$$\text{Stub length} = \frac{\left[\frac{\lambda_{max}}{8} \right]}{\tau} \times 12$$

... in inch. (12)

The mathematical equation from 1 to 11 are used to develop flow-chart and MATLAB program.

III.FLOWCHART FOR LPDA DESIGN



IV. MATLAB PROGRAM FOR LPDA

Equations (1–11) are implemented in MATLAB program.

%DESIGNING OF A LOG-PERIODIC ANTENNA FOR ANY FREQUENCY RANGE

%Designed by Dnyandev B. Patil.

```

clc
clearall
disp('DESIGNING OF A LOG-PERIODIC ANTENNA FOR ANY FREQUENCY RANGE ');
disp(' ');
a=float('double');
l(100)=float('double'); Rn(100)=float('double');
gtl=0.0;gt2=0.0;gt3=0.0;
Fmin=input('Enter the value of lower frequency in MHz, Fmin= ');
Fmax=input('Enter value of upper frequency in MHz, Fmax= ');
dmax=input('Enter diameter of largest element (in inch), dmax= ');
  
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tau=input('Enter the value of tau (0.7 to 0.95), tau= ');
Fmin=Fmin*10^6;Fmax=Fmax*10^6;
sigma= 0.243*tau - 0.051;
disp(' ');
disp(['The value of sigma (optimum sigma ) is ',
num2str(sigma)]);
alpha=atand((1-tau)/(4*sigma));
alpha1=2*alpha;
disp(['Full apex angle, alpha =',num2str(alpha1),' deg']);
Bar=1.1+(7.7*((1-tau)^2)*cotd(alpha));
fprintf('Bandwidth of Active region =%f MHz \n',Bar);
B= Fmax/Fmin;
disp(['Bandwidth,B= ', num2str(B),' MHz']);
Bs=(B*Bar);
fprintf('Designed bandwidth =%f MHz \n',Bs);
c=3*10^8;
Lmax=(c/Fmin); %meter
disp(['The Maximum wavelength in meter, Lmax = ',
num2str(Lmax)]);
l2=Lmax*3.2805; %feet
fprintf('Max wavelength =%f feet\n',l2);
L=(Lmax/4)*(1-(1/Bs))*cotd(alpha);
L1=L*3.2805;%feet
fprintf('Total length of structure =%f feet\n',L1);
Vapex=(2*(l2/2)*sigma)/(1-tau);
disp(['The Maximum vertual apex length, Vmax= ',
num2str(Vapex),' feet']);
N=1+(log(Bs)/log(1/tau));
n=round(N);
fprintf('No. of elements are, N =%f \n',n);
sigma1=sigma/sqrt(tau);
fprintf('Relative mean spacing =%f \n',sigma1);
LN=l2/2; %length of nth element in feet
Lnn=LN*12;
stub_length=((l2/8)/tau)*12;
disp(['stud length =',num2str(stub_length),' inch']);
za=120*(log((LN*12)/dmax)-2.25);
fprintf('Average characteristic impedance,za =%f ohms
\n',za);
Rin=50;
Zrel=za/Rin;
fprintf('Relative characteristic impedance, Zrel =%f ohms
\n',Zrel);
VAR=1.2;
z0=VAR*Rin;
fprintf('Characteristic impedance of Feeder line, Z0 =%f
ohms \n',z0);
R0= z0/(sqrt(1+(z0/(4*sigma1*za)))));
disp(['Mean Radiation resistance level of input impedance
= ',num2str(R0),' ohm']);
dir= 10*log(4*(Lmax/2)/Lmax) ;
disp(['Directivity =',num2str(dir),' dB']);
fs=(dmax*(cosh(z0/120)))*2.54;
s=Vapex*30.48;
fprintf('Centre-to-centre spacing of feeder line conductor
=%f cm\n',fs);
L(n)=LN*12;
d(n)=s;
k=n;
disp(' ');
disp(' ');

```

```

for i=n-1:-1:1
L(i)=L(i+1)*tau ;
r(k)=d(i+1)*(1-tau);
d(i)=d(i+1)-r(k);
gt1=gt1+L(i) ;
gt2=gt2+r(k);
k=k-1;
end
element=n;
for j=1:n
disp(' ');
fprintf(' Length of %d th element is %f inch
\n',j,L(element));
gt3=(gt3+r(j));
element=element-1;
fprintf(' distance of %d element from 1st element is %f
inch\n',j,(gt3/2.54));
distnc=element+1;
if(j<n)
fprintf(' Spacing between %d & %d element is %f cm
\n',j,j+1,r(distnc)) ;
end
end
fprintf(' Gross total length req. for all elements is %f inch
\n',gt1+Lnn)
fprintf(' Gross total space req. for all elements is %f
cm\n',gt2)

```

V. RESULT

Table I shows the log periodic dipole antenna design calculated values for Fmin 160MHz , Fmax 1900MHz , scale factor $\tau = 0.876$, spacing factor $\sigma = 0.161$ and the half apex angle $= \alpha 10.84$ using MATLAB program. The scale factor should be such that its value is less than one. The apex angle should not be too small or too large, since it affects the bandwidth of the antenna. As the frequency increases the spacing factor decreases.

TABLE I ANTENNA PARAMETERS

Sr. No.	Parameters obtained by program	
	Parameters	Values
1	Fmin	160 MHz
2	Fmax	1900 MHz
3	dmax	0.40 in
4	Tau	0.876
5	Sigma	0.161
6	Alpha	10.90
7	Bar	1.72 MHz
8	B	11.88 MHz
9	Bs	20.5 MHz
10	Lmax	1.78 m
11	L	7.655 feet
12	Vapex	8.02 feet
13	N	24
14	Stub length	10.53 in
15	Za	272.95 ohm
16	Zrel	5.45 ohm
17	Z0	60 ohm
18	Centre to centre	1.14 cm

Table II shows the obtained values from the MATLAB program. It includes the values of 24 elements at top, bottom side lengths, diameter of the each element in inches and spacing in cm.

TABLE II ANTENNA DESIGN

No. of Element	Antenna Design Parameters obtained by Program			
	Element length (L) Top side (in)	Element length (L) Bottom side (in)	Distance between R_n and R_{n+1} (cm)	Diameter of element (d) (in)
01	36.90	36.90	30.35	0.40
02	32.32	32.32	26.58	0.40
03	28.32	28.32	23.39	0.40
04	24.80	24.80	20.40	0.40
05	21.73	21.73	17.87	0.40
06	19.03	19.03	15.65	0.40
07	16.67	16.67	13.71	0.40
08	14.60	14.60	12.01	0.40
09	12.79	12.79	10.52	0.40
10	11.21	11.21	09.21	0.40
11	09.82	09.82	08.08	0.40
12	08.60	08.60	07.07	0.40
13	07.53	07.53	06.20	0.40
14	06.60	06.60	05.43	0.40
15	05.78	05.78	04.76	0.40
16	05.06	05.06	04.17	0.40
17	04.43	04.43	03.65	0.40
18	03.88	03.88	03.20	0.40
19	03.40	03.40	02.80	0.40
20	02.98	02.98	02.42	0.40
21	02.61	02.61	02.15	0.40
22	02.28	02.28	01.88	0.40
23	02.00	02.00	01.65	0.40
24	01.76	01.76	-	0.40

The LPDA is constructed by using two rod alumina type with 24 elements mentioned in table II. Its photograph is shown in fig. 2.



Fig.2. Photograph of designed LPDA

VI. CONCLUSION

Using mathematical relations of tau (τ), sigma (σ) and half apex angle (α), various parameter of LPDA antenna such as bandwidth, length of structure, number of elements, characteristic impedance, radiation resistance,

relative spacing between the element, stub length etc are to be calculated in designing. To calculate these antennas parameter manually is complicated and time consuming. For developing the code, flow-chart is drawn to calculate all these parameters of LPDA. The MATLAB general program was developed to calculate the antenna parameter and structural dimensions for any range of frequencies.

The MATLAB based program provides calculation in the fraction of points which helps to design more accurate structure of LPDA antenna. The MATLAB tools and built-in math functions enable us to explore multiple approaches and reach a solution than traditional programming languages. Using developed MATLAB program, antenna parameters and structure of LPDA for any frequency range can be easily obtained.

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BIOGRAPHIES



Vijay Kale (M.Sc., M. Phil., Ph.D., PGDIM, ADCSSA) is working as

Assistant Professor (Department of Electronic science, KTHM College, Nashik, Maharashtra, India). He has been in the teaching profession (UG and

PG) since last 27 years. He has been presented research paper in international conferences (USA, Bangkok). He published research papers in national and international journals. He received R. Chandrasekhar award from Indian Physics Association (IPA), Savitribai Phule Pune University. He has written five books. He is working as research guide to M. Phil. and M.Sc. (Electronic Science) students. He is presently working on e-CALLISTO, DAS, ARM microcontroller based sensor application, Wireless sensor application.



Dnyandev Patil is working as M. Phil. student (Department of Electronic science, KTHM College, Nashik).

His research activity is in antenna designing and Sensor based embedded system. He is presently working on e-CALLISTO.