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Radiation Pattern and VSWR Characteristics of LPDA 160MHz to 1300MHz Frequency

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Abstract: Antenna is important element in communication system which is most responsible for satisfactorily working of the system. The Log Periodic Dipole Array (LPDA) antenna consists of a system of driven elements; but not all of them in the system are active on a single frequency of operation. The length and spacing of the elements of a log-periodic antenna increase logarithmically from one end to the other. Depending on its design parameters, the LPDA can be operated over a range of frequencies. The parameters such as radiation pattern and voltage standing wave ratio (VSWR) are important to study/check antenna quality. This paper represents the details of constructed LPDA of frequency range of 160MHz to 1900MHz with 24 elements using MATLAB program. The antenna is also designed and simulated using CST MICROWAVE STUDIO® (CST MWS). Using antenna trainer kit (Transmitter, Receiver) frequency range up to 1300MHz, LPDA pattern and VSWR results are reported. The nature of patterns at 400MHz and 1000MHz are approximately same. The VSWR values are within 1 to 2. This indicates that the constructed LPDA is of good quality.

Keywords: Antenna Parameters, LPDA, Radiation Patterns, VSWR, CST Studio, MATLAB.

I. INTRODUCTION

Antennas are a fundamental component of modern communications systems. An antenna acts as a sensor between a guided wave in a transmission line and an electromagnetic wave in free space. Antennas demonstrate a property known as reciprocity that is an antenna will maintain the same characteristics regardless if it is transmitting or receiving. An antenna must be tuned to the same frequency band that the radio system to which it is connected; otherwise reception and/or transmission will be impaired [1]. When a signal is fed into an antenna, the antenna will emit radiation distributed in space. A graphical representation of the relative distribution of the radiated power in space is called a radiation pattern [2]. The radiation pattern of an antenna is of principle concern when engineering a communications system. There are many different ways to manipulate a radiation pattern to meet the demands of a specific task [3,4]. The Log Periodic Dipole Antenna (LPDA) was invented by Raymond and variants by Paul Mayes at the University of Illinois in 1958. It was first built by Du Hamel and Dwight E. Isbell, an undergraduate researcher in the ECE antenna laboratory in 1958. It is an important type of frequency independent antenna. The length and spacing of the elements of a log-periodic antenna increase logarithmically from one end to the other. In telecommunication, a log-periodic antenna is a broadband, multi-element, unidirectional, narrow-beam antenna that has impedance and radiation characteristics that are regularly repetitive as a logarithmic function of the excitation frequency [5, 6].

The MATLAB (Matrix Laboratory) program is developed to design LPDA for Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO). Design uses three geometric parameters, a scale factor τ that specifies the relative lengths and a spacing factor σ that specifies the relative spacing of the antenna elements. A third parameter, α, is one-half the apex angle and is derived from τ and σ [7]. 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. LPDA design calculated values for Fmin. 160MHz, Fmax. 1900MHz, scale factor τ=0.876, spacing factor σ= 0.161 and the half apex angle= α 10.84 using MATLAB program [8]. LPDA antenna is constructed for frequency range of 160MHz to 1900MHz with 24 elements is shown in Fig.1.

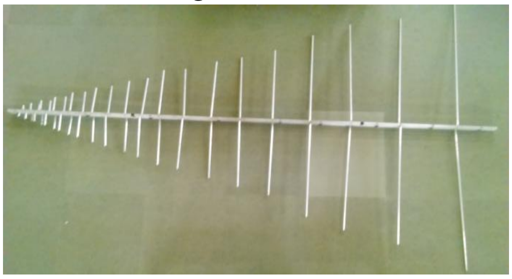

Fig. 1. Photograph of constructed LPDA

The antenna design and simulator provides an integrated development environment (IDE), a GUI-based antenna design tools are available to design and simulate an antenna [9]. It allows designer to find the parameters of antenna that need costly equipment, setup and tools in practice. The LPDA designed using CAD tool and simulated to obtain antenna parameters such as directivity, gain, antenna pattern etc. CST MICROWAVE STUDIO® (CST MWS) is a specialist tool for the 3D EM simulation of high frequency components. CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas [10].

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The Voltage Standing Wave Ratio (VSWR) is an indication of how good the impedance match is. VSWR is often abbreviated as SWR. A high VSWR is an indication that the signal is reflected prior to being radiated by the antenna [11]. A VSWR of 2.0:1 or less is considered good. Most commercial antennas, however, are specified to be 1.5:1 or less over some bandwidth. For efficient transfer of energy, the impedance of the radio, the antenna, and the transmission line connecting the radio to the antenna must be the same [12]. Radios typically are designed for 50-ohm impedance and transmission lines used with them also have 50-ohm impedance. Efficient antenna configurations often have impedance other than 50 ohms; some sort of impedance matching circuit is then required to transform the antenna impedance to 50 ohms [13].

For pattern measurement it is important to choose a distance sufficiently large to be in the far-field, well out of the near-field. The minimum permissible distance depends on the dimensions of the antenna in relation to the wavelength. The accepted formula for this distance is $R_{min}= 2D^2/ \lambda$ Where, r = minimum distance from the antenna, D= largest dimension of the antenna and λ = wavelength [14, 15].

II. RADIATION PATTERN OF LPDA

To obtain radiation pattern, Signet Pvt. Ltd. antenna trainer kit is used. The transmitter transmits the frequency from 30MHz to 1300MHz is shown in Fig 2.

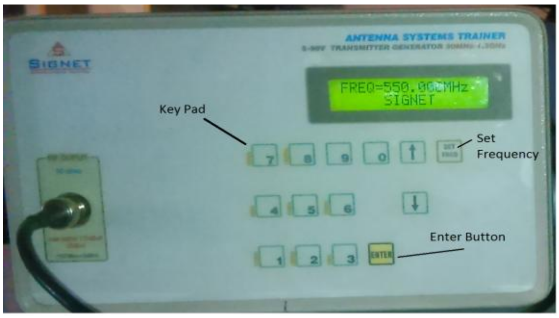

Fig. 2. S-99V Transmitter

The frequency can be set with built-in keypad and it was shown on 2x16 LCD display. It is also provided a DIN connector to connect transmitter S99V to receiver S-99R via 5pin DIN plug cable. Its transmitting signal level is 115 dBuV±5dB. The output impedance of terminal is 50Ω.

Fig. 3. S-99R Receiver

The receiver S-99R used to measure RF signal level is shown in Fig. 3. Its frequency range is from 50MHz to 1300MHz. Receiver has provided different connectors to connect such as stepper motor, printer and PC. It has also a DIN connector to connect S-99R to S99V via 5pin DIN plug cable. For obtaining polar diagram antenna is rotated by 1 or 5 degree by built-in stepper motor and the readings are stored in the memory of the unit. Polar diagram data can be coupled using RS232 to PC or printer.

Centronics connector can be connected to stepper motor for antenna rotation or used to print hard copy of polar plot using Epson 1x800 or compatible printer. The RS232 interface provides connectivity for PC.

Procedure for obtaining antenna patterns

Steps for obtaining antenna pattern:

a. Connect the transmitter to transmitting antenna and Power on the transmitter.
b. Set the frequency within the range of transmitter frequency for transmitting using “Set Freq” button and enter frequency using key pad, then press “Enter” button. Now display should show transmitting frequency just entered/set.
c. Connect the receiver to stepper motor positioner via Centronics interface. The connections are shown in Fig. 4.

Fig. 4. Stepper motor rotator and S-99R receiver connection

d. Power on the receiver and stepper motor unit. This will show “stp” on lower right corner of LCD. The arrangement of LPDA and stepper motor is shown in Fig 5.

Fig.5. Arrangement of LPDA and stepper motor

e. Set the same frequency as transmitting using keypad.
f. Now press “capture antenna DATA” button and press “Enter”. This prompt is shown on LCD.
g. The LCD will prompt to “Enter Array” either 1 or 2 and then press “Enter” to go next step.
h. Now the selection will be shown on LCD as frequency is 1000MHz & Array 1 is selected. To continue press “Enter” and is shown in Fig. 6.

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Fig. 6. Selected frequency parameter

i. Connect and adjust the stepper motor positioner such a way that transmitting and receiving antenna will point to each other. This is the 0-degree position of the polar plot of antenna and then to press enter to continue.

j. Select the rotating angle by entering 1 for 1 degree or 5 for 5 degrees. Press “Enter” to continue and starting measurement.

k. After completion of measurement, connect serial cable to RS232 interface of PC and Receiver and “Enable Serial” button on Receiver. This will show “serial enabled” on LCD display of receiver. It is shown in Fig. 7.

l. Connect hard lock key to USB port of PC and start application (SI3001) from desktop and select “Connect Receiver” from dropdown menu “RS232”.

m. Select “2D” polar plot from dropdown menu “Capture”.

n. This will import data captured by receiver for selected frequency and software will plot polar plot for the same. The obtained radiation pattern of constructed LPDA is shown in result section.

Fig. 7. Serial enable prompt

III. VSWR OF LPDA

The steps to measure VSWR of LPDA is as follows.

a) Connect one end of DIN cable into the socket of DIN cable at back panel of receiver and other end of cable to the back panel of transmitter. Turn on receiver, transmitter and enable serial interface.

b) Connect output of transmitter to the one end of 5 dB attenuator and other end of attenuator to one end of the directional coupler. Connect another end of directional coupler to the designed LPDA.

c) Now for measuring incident wave (Vi), make arrangement as shown in Fig. 8.

Fig. 8. Connections measurement of incident power

d) Open SI3006 software of signet Pvt. Ltd. and connect to serial. Now click on “VSWR/Spectrum” in Menu bar. The screen shot is shown in Fig. 9.

e) Click on “set (160-1300)” and set start frequency, stop frequency and No of steps.

f) After setting frequency parameters click “OK”.

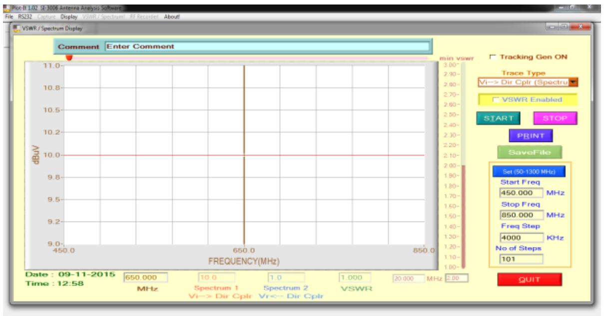

Fig. 9. VSWR Spectrum window

g) Then check “Tracking gen ON” and click on “Start”. This will calculate incident wave voltage, V_i. Its plot is shown in Fig.10.

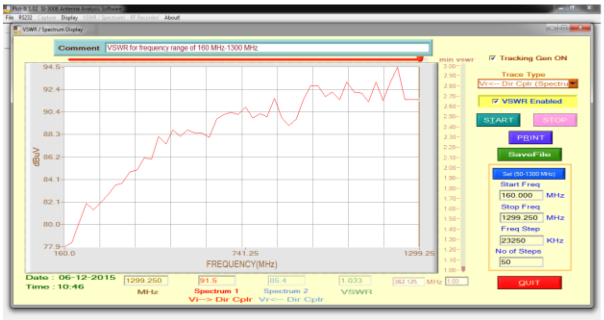

Fig.10. Input Vi Power Window

h) After finishing process make arrangement of the coupler as shown in Fig.11 to obtain reflected power.

Fig.11. Connections to measure reflected power

i) Check “Tracking gen ON” and select Vr←Dir coupler from dropdown box and click on “Start”.

j) To obtain VSWR plot for designed LPDA. Click on “Print” to print plot using printer connected to receiver.

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IV. RESULTS

The LPDA calculated values for Fmin. 160MHz, Fmax. 1900MHz, scale factor τ=0.876, spacing factor σ= 0.161 and the half apex angle= α 10.84 using MATLAB program. The antenna is constructed using 24 elements. Using CST studio suit 2013, the simulated radiation pattern at 1000MHz is shown in Fig. 12.

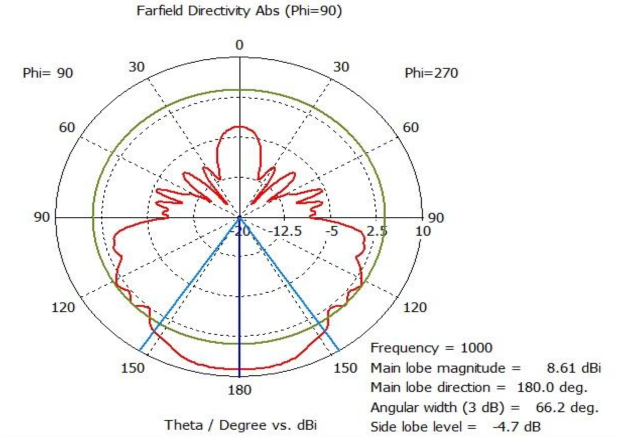

Fig. 12. Radiation pattern using CST studio 2013

The constructed LPDA has a boom length of 8feet and width 6feet which cover the range from 160MHz to 1.9GHz using twenty four (24) alumina metal elements. The lengths of elements are as high as 36.90inch and as low as 1.76inch. The radiation pattern obtained using the above mentioned experimental setup and procedure for 1000MHz is shown in Fig. 13.

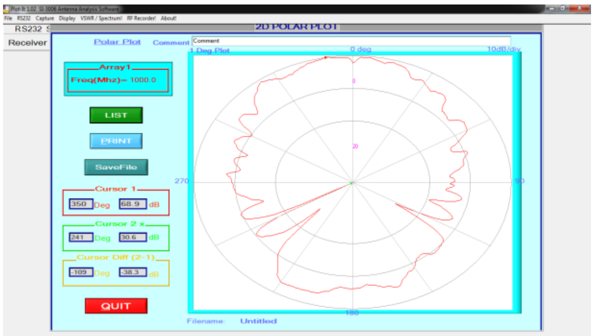

Fig. 13. Radiation pattern for frequency 1000 MHz

At 400MHz, the nature of radiation pattern is shown in Fig. 14.

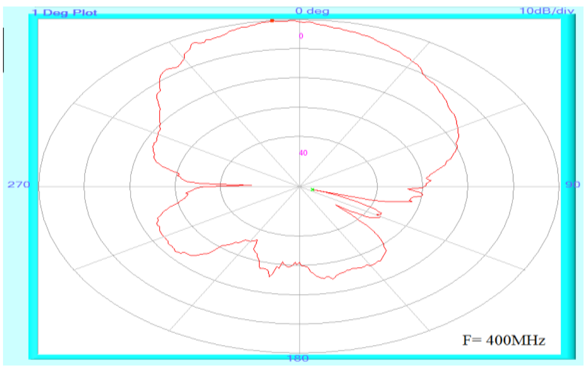

Fig. 14. Radiation pattern at 400MHz

The nature of radiation pattern of 400MHz and 1000 is approximately same for the constructed LPDA. It indicates that the patterns are essentially independent of frequency.

Using CST Studio 2013, the simulated VSWR is shown in Fig.15. The values of VSWR at low frequencies from 160MHz to 700MHz is within 1 to 1,5. At high frequencies, VSWR was increased up to 2.7.

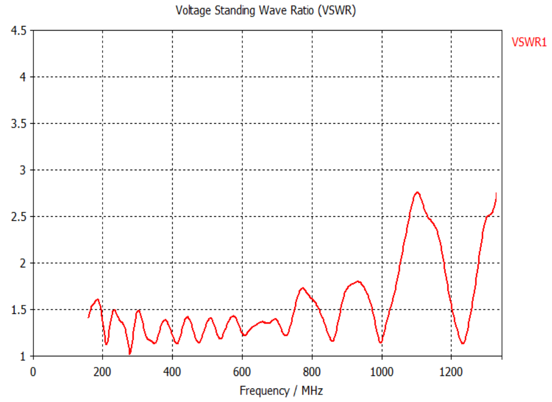

Fig. 15. Plot of VSWR using CST studio 2013

The experimental set up of VSWR includes the transmitter, receiver, a special connector setting to measure incident, reflected power. In this hardware as well as software setting (like range of frequency, incident or reflected etc.) are required. Using the procedure, the graphical representation of input power, the reflected power and the VSWR is shown in Fig. 16. From the plot, placing the mouse pointer at particular frequency, the exact value of VSWR is displayed at the bottom in a small rectangular box.

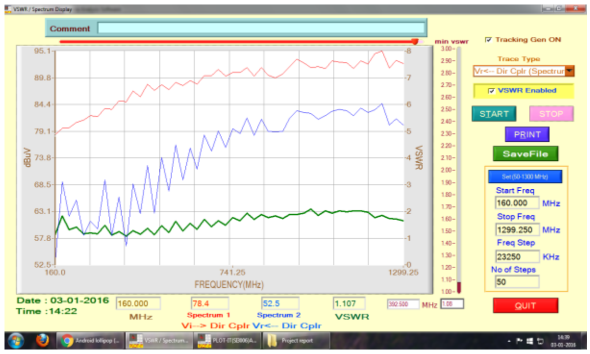

Fig.16. Plot of input Vi, reflected Vr and VSWR

TABLE 1. VALUES OF Vi, Vr & VSWR AT DIFFERENT FREQUENCIES.

Sr. No.	Freq. MHz	Vi (mV)	Vr (mV)	VSWR
1	160	8.32	0.43	1.11
2	206.5	9.78	1.29	1.3
3	253	11.62	0.84	1.16
4	299.5	12.59	0.97	1.17
5	346	14.97	0.83	1.12
6	392.5	17.79	0.66	1.08
7	439	19.96	1.37	1.15
8	485.5	22.91	1.39	1.13
9	508.75	25.41	4.96	1.49
10	555.25	27.55	6.61	1.63
11	601.75	28.85	6.17	1.54
12	648.25	32.36	8.32	1.69
13	694.75	37.16	9.13	1.65
14	741.25	34.68	9.55	1.76

15	764.5	34.68	8.52	1.65
16	811	31.99	8.23	1.69
17	857.5	32.74	9.02	1.76
18	904	33.5	9.02	1.74
19	950.5	47.32	14.46	1.88
20	1020.25	39.82	11.89	1.85
21	1066.75	45.19	14.29	1.92
22	1113.25	43.66	14.46	1.99
24	1206.25	53.71	14.8	1.76
25	1252.75	38.46	10.36	1.74
26	1299.25	42.66	10.36	1.64

In a plot, red, blue and green color plots are of incident, reflected and the VSWR respectively. Table 1 shows the numerical values of input, reflected power and VSWR at different frequencies in the range of 160MHz to 1300MHz. The VSWR values are within 1 to 2. At low frequencies around 160MHz to 500MHz, VSWR values are very close to 1.1. At high frequencies, it was increased but below 2. This indicates that the designed and constructed LPDA is of good quality.

V. CONCLUSION

The linearly polarized LPDA is the most practical antennas provide general broadband transmission and reception in wide range of frequency. Although it consists of a system of driven element, but not all elements in the system are active on a single frequency of operation. Due to different lengths and different relative spacing, it allows changes in frequency to be made without greatly affecting the electrical operation. The MATLAB general program was developed to calculate the antenna parameter and structural dimensions. The MATLAB based program provides calculation in the fraction of points which helps to design more accurate structure of LPDA antenna. CST studio suit 2013 is also used to design and simulate LPDA antenna and its parameters. It provides easy way to draw the structure by means of GUI. Its GUI interface is very powerful so any beginner can draw and design antenna structure. Boundary conditions and mesh setting allows designer to reduce solving time of solver. Different far-field patterns, e-field patterns and many more can be generated using its powerful solver. Form generated result one can view 2D or 3D antenna far-field patterns. It provides animation of current distribution in antenna structure for e-field. So how current is distributed for selected frequency is easily viewed.

The nature of radiation pattern obtained using the experimental setup and procedure for 400MHz and 1000MHz is approximately same. It means that the patterns are essentially independent of frequency. The VSWR values are within 1 to 2. This indicates that the designed and constructed LPDA is of good quality and can be used for different applications such as CALLISTO.

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BIOGRAPHIES

Vijay S. Kale (M.Sc, M.Phil, Ph.D, PGDIM, ADCSSA) is working as Associate Professor (Department of Electronic science, KTHM College, Nashik, Maharashtra, India). He has been in the teaching profession (UG and PG) since last 28 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), Pune chapter, Savitribai Phule Pune University. He has written five books. He is working as a project guide for M.Sc. (Electronic Science) and research guide to M. Phil. students. He has worked on several academic committees of Savitribai Phule Pune University. He has worked as a resource person in refresher course, seminars, workshop etc. He is presently working on ARM microcontroller based sensor application, Wireless sensor application, e-CALLISTO etc.

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 had completed project entitled Smart Energy Meter and Wind Speed Measurement using microcontroller.

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