Broadband Microstrip Log Periodic Dipole Array Antenna for Wireless Applications

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Abstract
The increasing demands of wireless, short range and high data rate transmissions pushed to propose different bands of the frequency spectrum, in order to support high data rate wireless communications. As a matter of fact, planar antennas are widely used because of their low profiles, easy design and fabrication. The Microstrip antenna offers compact size, low cost and an ease of integration into front-end circuits. The main disadvantage of these antennas is narrow bandwidth. To increase the bandwidth of Microstrip antennas, Log Periodic Dipole Arrays (LPDA) are introduced. In this article, a log-periodic dipole array printed on FR4 material (ε=4.3) for broadband applications i.e. from 1GHz to 10GHz is used for wireless communications. The proposed antenna has to be designed, optimized using Altair FEKO and then realized. The design methodology of proposed antenna is also to be verified by using commercially available software like C, python and MATLAB. The performance of the proposed antenna is to be verified by using radiation characteristics like return loss, VSWR, impedance, bandwidth, Directivity and gain. The proposed antenna is to be fabricated and the results will be compared with the simulated antenna results.

Keywords: LPDA, FEKO, Python and MATLAB.

I. INTRODUCTION
An antenna can be explained as a transitional structure between free space and a guiding device. Consider a basic mobile phone or a TV or even a radio; all of these devices contain a simple, low profile, light weight, low cost device for transmission and reception of signals called a micro strip antenna. Micro strip antennas have developed considerably during the past few decades, which have helped in overcoming many of its limitations. There has been a series of developments in the feeding techniques size, thickness, materials, and design. These developments have helped us in increasing the bandwidth and the gain of the antennas. Reducing in the size of the antenna makes it portable and more convenient to use. Microstrip antennas being easy to design and manufacture are used in various fields where low-profile antennas are required.

This article is aimed at designing a broadband Microstrip Log Periodic Dipole Array. The LPDA contains 22 pairs of parallel elements on both sides of the microstrip feed line runs along the centre of the antenna. The LPDA is designed using the design equations of LPDA. By using the equations the number of elements, length of dipole, position of dipole, width of the dipole, boom length and terminating stub are calculated. The phase reversal method was used, where the elements are shifted at 180 degrees phase shift alternatively. The proposed antenna is printed on FR-4 substrate with relative permittivity 4.3. The observations were made based on radiation pattern, bandwidth, return loss, VSWR and gain and the results were noted down. The design was modified considering the necessary constraints to get the optimum results.

III. DESIGN METHODOLOGY
One of the most important parameters that describe log periodic antennas in general is presented in Equation for τ. This parameter is known as the scaling factor. This scaling factor allows the antenna dimensions to remain constant in terms of wavelength. The condition is necessary to maintain the same impedance and radiation characteristics over a wide range of frequencies. This factor should be less than 1 and when the frequency is increased by input impedance, VSWR, bandwidth, Directivity and gain. The proposed antenna is to be fabricated and the results will be compared with the simulated antenna results.
The longest and shortest lengths of the dipole elements are about λ/2. As their existing type of design includes more elements in the active region that are closer together. This means that if two of the parameters are specified, the third one can be found through this equation. Using this equation, one can find the required elements separated by larger distance.

In practice, a slightly larger bandwidth (Bs) is usually designed than the actual one (B) and they are related by equation .5:

\[ B_s = B \cdot B_{ar} \]  \hspace{1cm} (5)

Where,

- \( B_s \) = Designed bandwidth
- \( B = \) Required bandwidth = \( f_{max}/f_{min} \)
- \( B_{ar} = \) Bandwidth of active region

The total length of the structure \( L \), from the shortest (\( l_{min} \)) to the longest (\( l_{max} \)) element, is given by equation .6:

\[ L = 0.5(\lambda_{max}/4)[1-(1/ B_{struc})] \cot \alpha \]  \hspace{1cm} (6)

Where equation .7 gives the Maximum wavelength:

\[ \lambda_{max} = \nu/f_{min} \]  \hspace{1cm} (7)

The number of elements from the geometry of the system is given by equation 4.4.8:

\[ N = 1 + \ln \left( \frac{B_{struc}}{\ln (1/\tau)} \right) \]  \hspace{1cm} (8)

Centre-to-centre spacing of feed line is given by equation .9:

\[ s = d \cosh (Z_0/120) \]  \hspace{1cm} (9)

Where characteristic impedance of parallel feed line is taken as 50 Ω and is given by equation .10:

\[ Z_0 = \frac{R_0^2}{8\sigma Z_a} + R_0 \sqrt{\frac{R_0^2}{8\sigma Z_a} + 1} \]  \hspace{1cm} (10)

Where relative mean spacing is given by equation .11:

\[ \alpha' = \sigma/B \]  \hspace{1cm} (11)

Average characteristic impedance of elements is given by equation .12:

\[ Z_a = 120[\ln (l_a/d_a)] - 2.25] \]  \hspace{1cm} (12)

Theoretical Calculations:

- Min frequency: 1000MHz
- Max frequency: 10000MHz
- Boom length: 293.6 mm
- Gain: 7.30 dB
- Tau: 0.847
- Sigma: 0.155
- Bandwidth (active region): 1.83
- Bandwidth (structural): 32.95
- Bandwidth (effective): 18.00
Table 1. Dimensions of the Elements of LPDA

<table>
<thead>
<tr>
<th>NUMBER OF ELEMENTS (n)</th>
<th>LENGTH OF DIPOLE (l_n) m</th>
<th>POSITION (R_n) in mm</th>
<th>DIAMETER (d_n) in mm</th>
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<tbody>
<tr>
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<td>20.06</td>
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<tr>
<td>2</td>
<td>127</td>
<td>46.4</td>
<td>16.87</td>
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<td>3</td>
<td>107.6</td>
<td>85.7</td>
<td>14.19</td>
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<td>4</td>
<td>91</td>
<td>119</td>
<td>11.93</td>
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<td>5</td>
<td>77</td>
<td>147.2</td>
<td>10.04</td>
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<tr>
<td>6</td>
<td>65.2</td>
<td>171</td>
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<tr>
<td>7</td>
<td>55.2</td>
<td>191.2</td>
<td>7.10</td>
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<tr>
<td>8</td>
<td>46.8</td>
<td>208.3</td>
<td>5.97</td>
</tr>
<tr>
<td>9</td>
<td>39.6</td>
<td>222.8</td>
<td>5.02</td>
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<tr>
<td>10</td>
<td>33.6</td>
<td>235.1</td>
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<tr>
<td>11</td>
<td>28.4</td>
<td>245.5</td>
<td>3.55</td>
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<td>12</td>
<td>24</td>
<td>254.3</td>
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<tr>
<td>22</td>
<td>4.6</td>
<td>293.6</td>
<td>0.54</td>
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</tbody>
</table>

The Proposed antenna is simulated using commercially available 3D-Simulation tool FEKO. The front view, rear view and porting views are depicted in figures 1 2 & 3 respectively.

Fig 1: Front View of Designed Antenna

Fig 2: Rear View of Designed Antenna

Fig 3: Edge porting View of Designed Antenna

Here the Upper surface acts as the positive port and Lower surface acts as the Negative port.

IV. RESULTS & DISCUSSION

The Simulated VSWR plot is depicted in figure 4. The VSWR< 2 for the frequency range from 1GHz to 7.5 GHz. It shows the broadband nature because almost covering the Bandwidth of 6GHz.

Fig 4: VSWR plot of the designed antenna
To validate the frequency of operation of the designed antenna $|S_{11}|$ plot is also displayed in fig.5. The Return loss value is satisfying the $|S_{11}| < -10\text{dB}$ criterion for the entire frequency from 1 GHz to 7.5 GHz. The minimum return loss is achieved at 4GHz.

The 2D- Radiation plot the designed antenna is shown in figure.6. It shows an effective gain at 2 GHz, 3 GHz, 6 GHz, 7GHz and 9 GHz of 10dB respectively. The 3D- Radiation plots are depicted in figures 7, 8,9,10 & 11 respectively.

The 3D-Radiation plot at 2GHz is shown in figure.7. It shows the 10dB of gain at this frequency. The microstrip antennas are suffering from low gain. The proposed design can be effectively used to overcome the low gain problems.

The 3D-Radiation plot at 3GHz is shown in figure.8. It shows the 8dB of gain at this frequency. The microstrip antennas are suffering from low gain. The proposed design can be effectively used to overcome the low gain problems.

The 3D-Radiation plot at 4GHz is shown in figure.9. It shows the 5dB of gain at this frequency.

The 3D-Radiation plot at 5GHz is shown in figure.10. It shows the 5dB of gain at this frequency.
The 3D-Radiation plot at 6GHz is shown in figure.11. It shows the 10dB of gain at this frequency. The microstrip antennas are suffering from low gain. The proposed design can be effectively used to overcome the low gain problems.

The surface current plots of the simulated antenna are depicted in figures 12, 13, 14, 15 & 16. It is having maximum effective surface current of 27 dBA/M.

V. CONCLUSION

In this paper, Broadband Microstrip Log Periodic Dipole Array Antenna is presented. The designed antenna is effective as the VSWR is below 2 and S-parameters are well under -10dB with a power effectively transferred to antenna and only 10 percent is reflected back. This antenna can be used for satellite communication, Radio Broadcasting, Wi-Fi channels and much other purpose. The radiation plots are also shows the effective gain of dB.

REFERENCES


