L-Shaped Slot Broadband Single Layer Rectangular Patch Antennas

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Abstract- A single L-slot rectangular patch antenna gives an impedance bandwidth (-10dB below return loss) upto 25.9% with an average gain of about 8.11 dBi over the entire passband and peak gain of 9.92 dBi. The average directivity of about 8.77 dBi over the entire passband and peak directivity of 10.25 dBi. The average efficiency is found to be about 92.4%. Another patch antenna with a double L-slot gives an impedance bandwidth (-10dB below return loss) of 32.53% with an average gain of about 8.684 dBi over the entire passband and peak gain of 9.67 dBi have been achieved. The average directivity of about 9.3 dBi over the entire passband and peak directivity of 9.95 dBi. The average efficiency is found to be about 93.3%. Air substrate (εr = 1) is used for simulation and foam (εr ≈ 1) is used to support patch for experimental purposes. Both simulated and measured results are presented.

Index Terms- Broadband patch antenna, single slot, double slot, L-slot.

I. INTRODUCTION

Design of broadband patch antennas with thick air or foam substrate have been quite popular owing to their simple structure, ease of fabrication and thickness modification and good radiation characteristics over the entire operating bandwidth. Some effective method of increasing bandwidth is also by using U-slot or Half U-slot (L-Slot). Half U-slot patch on multilayer substrate achieved 14.6% bandwidth with a peak gain of 8 dBi [1]. Half U-slot patch antenna with shorting wall has achieved bandwidth of 28% and gain of around 2 dBi [2] with a serious problem of distorted radiation patterns. Wideband folded L-slot shorted patch antenna has achieved bandwidth of 76% and peak gain of 8.5 dBi [3] with same problem of serious distorted radiation patterns and complicated structure. In this article simple single layer, single and double L-slot wideband rectangular patch antennas with impedance bandwidth of 25.9% and 32.53% with peak gain of 9.92 dBi and 9.67 dBi respectively are presented. The peak directivity are 10.25 dBi and 9.95 dBi respectively for both antennas. Half power beamwidth (-3dB beamwidth) of single L-slot at centre frequency (2.4 GHz) for E-total are 51.71° and 63.23° at phi 0° and 90° respectively. Then the half power beamwidth of double L-slot at centre frequency (1.873 GHz) for E-total are 57.51° and 62.73° at phi 0° and 90° respectively. The radiation patterns is also much improved. In this article two types of antennas are simulated and experimentally studied. The IE3D simulation software based on Method of Moments (MoM) is used for simulation and Agilent’s E5071B ENA series Network Analyzer and Anritsu 37269D Vector Network Analyzer are used for measurements.
II. ANTENNA DESIGN

Two antennas are analyzed and are named as Antenna 1 and Antenna 2. Their geometries are presented separately as follows.

Antenna 1 is having a single L-slot with patch dimensions of 110 X 52 mm². Dimensions of the Antenna 1 is as shown in Figs. 1.(a, b). The height (h) between patch and ground plane is 7 mm. The probe is fed at (X = 0, Y = -11 mm) from the patch centre.

All antennas are fed with SMA coaxial probe of 50Ω characteristic impedance with inner conductor of radius 0.6 mm and foam (\(\varepsilon_r \approx 1\)) is used to support the patch. Antennas dimensions are obtained after optimization by simulation software. The ground plane size is taken to be about three times patch size for experimental purpose for realization of semi-infiniteness.

III. ANTENNA ANALYSIS

For running simulations in IE3D, infinite ground plane is considered to ensure faster convergence.

Antenna 1 gives simulated results for impedance bandwidth (-10dB return loss) of 23.9% (2.115-2.69 GHz) of centre frequency.
(2.40 GHz). Experimentally measured impedance bandwidth is 25.9% (2.1-2.725 GHz) of centre frequency. The simulated average gain of Antenna 1 is 8.11 dBi over the entire passband and peak gain is 9.92 dBi. The simulated average directivity of Antenna 1 is 8.77 dBi over the entire passband and peak directivity is 10.25 dBi. The average efficiency of the Antenna 1 is about 92.4% (Gain= efficiency X Directivity). The Radiation patterns at centre frequency (2.4 GHz) with half power beamwidth (-3dB beamwidth) for E-total are 51.71° and 63.23° at phi 0° and 90° respectively. For the simulated radiation patterns of both antenna there is no back lobe as infinite ground plane is taken during simulation, hence its plots is shown only for upper half plot. The nature of polarization is shown by axial ratio (AR) versus frequency graph. All the simulated and measured results for return loss, gain and radiation patterns for Antenna 1 are as shown in Figs.3. (a-f).
Antenna 1 (a). Return loss vs Frequency graph (b). Gain vs Frequency graph (c). Directivity vs frequency graph (d) Measured radiation patterns at centre frequency (2.4 GHz) (e) Simulated radiation patterns at centre frequency (2.4 GHz) (f) Axial ratio vs Frequency graph.

Antenna 2 gives simulated result for impedance bandwidth of 30.42% (1.5883-2.15833 GHz) of centre frequency (1.87 GHz). Experimentally measured impedance bandwidth is 32.53% (1.5825-2.1975 GHz) of centre frequency. The simulated average gain of Antenna 2 is about 8.684 dBi over the entire passband and peak gain is 9.67 dBi. The simulated average directivity of Antenna 2 is about 9.3 dBi over the entire passband and peak directivity is 9.95 dBi. The average efficiency of the Antenna 2 is about 93.3% (Gain= efficiency X Directivity). The radiation patterns at centre frequency (1.87 GHz) with half power beamwidth (-3dB beamwidth) for E-total are 57.51° and 62.739° at phi 0° and 90° respectively. The nature of polarization is shown by axial ratio (AR) versus frequency graph. All the simulated and measured results for return loss, gain, directivity, radiation patterns and axial ratio for Antenna 2 are as shown in Figs.4. (a-f). It is obvious that the simulated and measured results are closely matching with each other.
Fig. 4. Antenna 2   (a). Return loss vs Frequency graph   (b). Gain vs Frequency graph   (c). Directivity vs frequency graph (d). Measured radiation patterns at centre frequency (1.87 GHz) (e) Simulated radiation patterns at centre frequency (1.87 GHz) (f) Axial ratio vs Frequency graph.

The measured and simulated plots are found to be much closed for both antennas. The performance of the proposed Antennas 1 & 2 as compared to other reference antennas is shown in table 1.

Table 1: Comparison

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Peak, Average Gain</th>
<th>BW Types</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref.[1]</td>
<td>8 dBi, 6 dBi</td>
<td>14.6%</td>
<td>Multilayer substrate, Simple structure and small bandwidth</td>
</tr>
<tr>
<td>Ref.[2]</td>
<td>Below 5 dBi, 2 dBi</td>
<td>28%</td>
<td>Shorting wall, Distorted radiation patterns and low gain</td>
</tr>
<tr>
<td>Ref.[3]</td>
<td>8 dBi, 6 dBi</td>
<td>76%</td>
<td>Folded L-slot, Shorted, Complicated structure and distorted radiation patterns</td>
</tr>
<tr>
<td>Antenna 1</td>
<td>9.92 dBi, 8.11 dBi</td>
<td>25.9%</td>
<td>Single layer single L-slot, Simple, good gain and less distortion of radiation patterns</td>
</tr>
<tr>
<td>Antenna 2</td>
<td>9.67 dBi, 8.684 dBi</td>
<td>32.53%</td>
<td>Single layer double L-slot, Simple, good gain and less distortion of radiation patterns</td>
</tr>
</tbody>
</table>
IV. CONCLUSION

Our designed antennas are single layer patch which can provide wide band impedance bandwidth with good gain over the entire passband. The single and double L-slots give wide impedance bandwidth with considerably good average gain over the entire passband and good radiation patterns. The directivity and efficiency of the antennas are also good. The structures are easy to fabricate and radiation patterns are also much better in comparison with other mentioned L-slot and half U-slot antennas and are also close to conventional microstrip patch antenna patterns. Our designed antennas have many advantages in terms of gain, bandwidth, directivity, radiation characteristics and simplicity.

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REFERENCES