Development & Design of Stacked Microstrip Patch Antenna for Wireless Application

K. Adithya¹ J. Ayyappan² P. Bharath³ Mrs. A. Mary Joy Kinol⁴
¹,²,³ UG Student ⁴ Assistant Professor
Department of Electronics & Communication Engineering
JEPPIAAR SRR Engineering College, India

Abstract—This project addresses the design of stacked microstrip patch antenna for wireless application. The proposed microstrip stack antenna has the operating frequency at 4GHz. The antenna is designed with FR-4 material as substrate that as the relative permittivity of 4.4 and loss tangent 0.02. The feeding technique used is microstrip feeding. The stacked microstrip antenna overcomes the limitations of normally narrowband microstrip antenna without altering the ground plane, which helps the antenna to achieve a unidirectional radiation pattern along with large bandwidth. The proposed antenna is suitable for various wireless applications. The proposed antenna is designed and simulated using HFSS (High Frequency Structural Simulator) software.

Key words: Microstrip Patch Antenna, Wireless Application

I. INTRODUCTION

Although a microstrip antenna has practical advantages, such as low profile and light weight, a single patch antenna has low gain (5–8dBi) and a narrow bandwidth. It is well known that a multilayer structure is a useful method to improve these problems. By stacking a parasitic patch on a fed patch, an antenna with high gain or wide bandwidth can be realized [8]. These characteristics of the stacked microstrip antenna depend on the distance between the fed patch and the parasitic patch. The microstrip antenna stacking a parasitic patch close to a fed patch has wide bandwidth, whereas the antenna stacking the parasitic patch at a spacing of approximately half a wavelength has high gain. Experimental studies [9–12] and theoretical studies [13–16] for the wide bandwidth approach have been reported. The Hankel transform [13, 14] and the spectrum domain method [15, 16] were applied to the stacked antennas. It has been reported that a stacked antenna with two patches spaced approximately half a wavelength apart has a high gain using numerical analysis with the wire grid model [17]. It has also been reported that an aperture-stacked patch microstrip antenna has a relative bandwidth of about 70%. The behavior of the antenna was explained in [18, 19]. Experimental investigation has shown that a stacked microstrip antenna has a high gain when the distance between the fed patch and the parasitic patch is 0.3–0.5λ [20–22]. However, these studies are investigations into wide bandwidth or gain enhancement and are limited to the analysis of the resonant frequency, impedance and far field.

This paper describes the design and performance of a single-feed stacked arrangement of rectangular patches on a glass epoxy FR-4 substrate. The proposed antenna will radiate at three frequencies. A much improvement in gain has been achieved.

II. ANTENNA DESIGN & RESULTS

A. Design Concept of Rectangular Microstrip Patch Antenna

Fig. 1: Structure of Microstrip Patch Antenna

- Width of Rectangular Patch is calculated using equation
  \[ W = \frac{c_0}{2f_r} \sqrt{\frac{2}{\varepsilon_r+1}} \]  
  \[ \text{(1.1)} \]

- Fringing effect of patch \(\Delta L\)
  \[ \Delta L = 0.412h \left( \frac{\varepsilon_{\text{reff}}+0.3}{\varepsilon_{\text{reff}}-0.258} \right)^{\frac{1}{2} \left( \frac{c_0}{f_r}\right)} \] 
  \[ \text{(1.3)} \]

- Effective length \(L_{\text{eff}}\)
  \[ L_{\text{eff}} = \frac{c_0}{2f_r \varepsilon_{\text{reff}}} \] 
  \[ \text{(1.4)} \]

- Rectangular Patch length
  \[ L = L_{\text{eff}} - 2\Delta \] 
  \[ \text{(1.5)} \]

B. Single-Layer Rectangular Microstrip Antenna

First, we have considered a single-layer rectangular patch antenna. This antenna is designed on a glass epoxy FR-4 substrate. The antenna is fed through a microstrip transmission line feed as shown in the fig 1(a). The dimensions of the antenna are listed in the table below. The simulation analysis of this antenna is carried out by HFSS (High Frequency Simulation Software). The fig 1(b) shows the return loss characteristics of the antenna. The proposed antenna resonates at 4GHz and gain of -2.69 is achieved as shown in the fig 1(c). Radiation pattern and VSWR are also simulated as shown in fig 1(d) and fig 1(e) respectively. The proposed antenna has the VSWR value as 2.5.
Development & Design of Stacked Microstrip Patch Antenna for Wireless Application

Fig. 2(a): Microstrip Patch Antenna with Single Layer

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate length $L_s$</td>
<td>24</td>
</tr>
<tr>
<td>Substrate width $W_s$</td>
<td>29</td>
</tr>
<tr>
<td>Patch length $L$</td>
<td>16</td>
</tr>
<tr>
<td>Patch width $W_2$</td>
<td>21</td>
</tr>
<tr>
<td>Height $h$</td>
<td>1</td>
</tr>
<tr>
<td>Dielectric constant $\varepsilon_r$</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Table 1: Parameters & Dimensions of Single Stack Antenna

Fig. 2(b): Return Loss

Fig. 2(c): Gain

Fig. 2(d): Radiation Pattern

Fig. 2(e): VSWR

C. Double-Layer Rectangular Microstrip Antenna

We have considered a double-layer rectangular patch antenna. The antenna consists of two layers, one with driven patch (were the feed is given) and other with the parasitic patch placed above driven patch at a distance $d=1$mm. This antenna is designed on a glass epoxy FR-4 for both the substrate. The antenna is fed through a microstrip transmission line feed for the driven patch as shown in the fig 2(a). The dimensions of the antenna are listed in the table below. The simulation analysis of this antenna is carried out by HFSS (High Frequency Simulation Software). The fig 2(b) shows the return loss characteristics of the antenna. The proposed antenna resonates at 4.1GHz, 6.5GHz & 8.25GHz and gain of 4.66 is achieved as shown in the fig 2(c). Radiation pattern and VSWR also stimulated as shown in fig 2(d) and fig 2(e) respectively. The proposed antenna has the VSWR value as 0.39.
Development & Design of Stacked Microstrip Patch Antenna for Wireless Application

Fig. 3(a): Double Layer Microstrip Stack Antenna.

Fig. 3(b): Return Loss

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ls2</td>
<td>24</td>
</tr>
<tr>
<td>Ws2</td>
<td>29</td>
</tr>
<tr>
<td>L2</td>
<td>16</td>
</tr>
<tr>
<td>W2</td>
<td>21</td>
</tr>
<tr>
<td>h2</td>
<td>1</td>
</tr>
<tr>
<td>εr2</td>
<td>4.4</td>
</tr>
<tr>
<td>d</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Parameters & Dimensions of Double Stack Antenna

Fig. 3(c): Gain

Fig. 3(d): Radiation Pattern

Table 3: Comparison Between Single & Double Layer Stack Antenna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Single layer</th>
<th>Double layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>S11 (dB)</td>
<td>-16.82</td>
<td>-32.80</td>
</tr>
<tr>
<td>Gain (dB)</td>
<td>-2.69</td>
<td>4.66</td>
</tr>
<tr>
<td>VSWR</td>
<td>2.5</td>
<td>0.39</td>
</tr>
<tr>
<td>Peak directivity</td>
<td>1.55</td>
<td>1.40</td>
</tr>
<tr>
<td>Radiated power (W)</td>
<td>0.0047</td>
<td>0.0077</td>
</tr>
<tr>
<td>Radiation efficiency</td>
<td>60.05%</td>
<td>74.43%</td>
</tr>
<tr>
<td>Front to Back ratio</td>
<td>74.91</td>
<td>75.08</td>
</tr>
</tbody>
</table>

Fig. 3(e): VSWR

III. CONCLUSION

This letter presents the design and performance of a single-feed stacked arrangement of rectangular patches on a glass epoxy FR-4 substrate. The designed antenna presents much improved impedance and bandwidths and larger gain than a single-layer antenna. These improved parameters are achieved without much increase in the thickness of the structure. The significant improvement in the bandwidth is the main achievement of the proposed work.

REFERENCES


