Enhancing the Bandwidth and Minimization of Return Loss of U Shaped Microstrip Patch Antenna for Wideband Applications

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Abstract: A simple design of U-shaped microstrip patch antenna with wide band characteristics is introduced in this paper. The analysis and simulation results of this design indicates that the proposed antenna exhibits wide band characteristics. The antenna patch is designed on the substrate having thickness of 1.6 mm, relative permittivity of 4.2 and loss tangent of 0.0013. The antenna utilizes the 50 Ω microstrip line feeding technique. IE3D software package of Zeland is used for the simulation of proposed antenna design. The U shaped microstrip patch antenna is designed in such a way that it achieves a wide bandwidth of 77.70% (VSWR<2) and minimum return loss of -64.42 dB at 2.156 GHz resonant frequency.

Keyword: Microstrip patch antenna, U shape, Microstrip Line feed, IE3D, Return Loss.

1. Introduction

Microstrip patch antennas are becoming useful increasingly because they can be printed onto a circuit board as well as they have some other advantages like low profile, easy fabrication, light weight and low manufacturing cost etc. Due to these attractive characteristics, microstrip patch antennas are very widespread within wireless industries and where rapidly increasing the demand of such light weight and compact antennas. Basically, microstrip patch antenna is a dielectric substrate panel sandwiched in between two conducting layers. The lower conducting layer is called ground plane and the upper conducting layer is known as patch.

However, microstrip patch antennas have drawbacks including narrow bandwidth, low power handling capability and low gain. But with technology advancement and extensive researches into this area these problems are being gradually overcome. There are many well known techniques for enhancing the bandwidth of these antennas, including increase of substrate thickness, the use of different feeding techniques, use of low dielectric substrates and the use of multiple resonators.

A wideband Microstrip patch antenna with microstrip feed line technique is presented in this paper. We have cut down a rectangular slot on patch to give it a shape of U. The proper optimization of proposed antenna design with varying the dimension of rectangular slot, results minimized return loss along with enhanced bandwidth of antenna.

2. Antenna Design

In designing the antenna, it is necessary to choose a suitable dielectric substrate of appropriate thickness (t), dielectric constant and loss tangent. The shape of patch, dielectric constant and thickness of substrate, feeding techniques are important factors which affects the performance of the microstrip patch antenna.

The mathematical equations for calculating the dimension of radiating patch antenna and size of ground plane are given below (1-6).

The width (W) of radiating patch is calculated by (12)

\[
W = \frac{c}{2f_r} \sqrt{\frac{2}{\varepsilon_{r_{eff}}+1}}
\]

The effective dielectric constant is calculated by (13)

\[
\varepsilon_{r_{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left[1 + 12 \frac{h}{W}\right]^{-\frac{1}{2}}
\]

The length extension is given by (3,8)

\[
\Delta L = 0.412h \left[\frac{\varepsilon_{r_{eff}}+0.3}{\varepsilon_{r_{eff}}+0.258}\right]^{\frac{1}{2}} + 0.264\left[\varepsilon_{r_{eff}}+0.8\right]^{\frac{1}{2}}
\]

The length of radiating patch is calculated by (2)

\[
L = \frac{c}{2f_r \sqrt{\varepsilon_{r_{eff}}}} - 2\Delta L
\]
Length and width of ground plane is calculated by [8]

\[ L_g = 6h + L \]  \hspace{1cm} (5)
\[ W_g = 6h + W \]  \hspace{1cm} (6)

Where \( f_r \) is the operating frequency, \( c \) is the velocity of light in the free space, \( W \) and \( L \) are the width and length of patch respectively, \( \varepsilon_r \) is the relative dielectric constant of the substrate and \( \Delta L \) is the length extension, \( W_g \) and \( L_g \) are the width and length of ground plane respectively.

The top view and geometry of the proposed antenna are presented in figure 1(a) and 1(b). It comprise of a finite ground plane having size of 46 mm x 56 mm. A slot of size 17.5 mm x 24.2 mm, etched on the rectangular shaped patch of size 36.4 mm x 46.4 mm.

The dielectric constant of the substrate is closely related with the bandwidth and the size of the microstrip patch antenna. Low dielectric constant of the substrate results wide bandwidth, while the high dielectric constant of the substrate results in smaller size of antenna. A trade-off relationship exists between antenna size and bandwidth [8]. The patch is fed by a 50 Ω microstrip line feed.

Table 1 indicates the optimized design parameter for the proposed antenna.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value(mm)</th>
<th>Parameter</th>
<th>Value(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_g )</td>
<td>56</td>
<td>( L_1 )</td>
<td>11.7</td>
</tr>
<tr>
<td>( L_g )</td>
<td>46</td>
<td>( L_2 )</td>
<td>17.5</td>
</tr>
<tr>
<td>( W_g )</td>
<td>46.4</td>
<td>( L_1 )</td>
<td>7.2</td>
</tr>
<tr>
<td>( L_p )</td>
<td>36.4</td>
<td>( h )</td>
<td>1.6</td>
</tr>
<tr>
<td>( W )</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric constant = 4.2</td>
<td>Loss tangent = 0.0013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is a challenging work to design a compact antenna operating with a wide impedance bandwidth which satisfies the demand of advanced wireless technology. Selecting the suitable slot shape, proper feeding technique and suitable dielectric constant, enhancement in bandwidth can be obtained.

### 3. Results and Discussions

"IE3D" 9.0.0 version of Zeland is used for the simulation and optimization of this antenna design. Figure 2 shows the simulated -10 dB return loss curve of the proposed antenna which resonate at frequency 2.156 GHz and also obtained the enhanced impedance bandwidth of 77.70 % with minimized return loss -64.42 dB. The figure 3 shows the VSWR curve, simulated on IE3D. The simulated radiation patterns of the elevation and azimuth of the proposed antenna are shown in figure 4.

![Figure 2: Simulated return loss of proposed antenna](image)

![Figure 3: Simulated VSWR of the proposed antenna](image)

![Figure 4: Simulated radiation pattern of the optimized proposed antenna. (a) Elevation pattern, (b) Azimuth pattern](image)
4. Sensitivity Analysis

A comprehensive numerical sensitivity analysis has been done in order to understand the effects of various dimensional parameters and to optimized the performance of the proposed antenna. The outcomes indicate that the minimization of return loss and bandwidth enhancement is closely depends on L1, L2 and L3. The comparison of the simulated return loss curves for different lengths of W, L1, L3 is performed here.

The figure 5 shows the comparison of return loss curves for W = 26.2 mm with variations in L1 and L3 and the optimum values for (W, L1, L3) is (26.2, 12.2, 7.2) mm. Table 2 shows the corresponding comparison data.

![Figure 5: Simulated return loss of the proposed antenna with different lengths of L1, L3](image)

<table>
<thead>
<tr>
<th>L1 (mm)</th>
<th>L3 (mm)</th>
<th>f1 (GHz)</th>
<th>f2 (GHz)</th>
<th>Bandwidth (%)</th>
<th>Return loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.2</td>
<td>8.2</td>
<td>1.267</td>
<td>2.904</td>
<td>78.11%</td>
<td>-29.85</td>
</tr>
<tr>
<td>8.2</td>
<td>12.2</td>
<td>1.553</td>
<td>2.921</td>
<td>61.122%</td>
<td>-30.58</td>
</tr>
<tr>
<td>12.2</td>
<td>7.2</td>
<td>1.273</td>
<td>2.896</td>
<td>77.86%</td>
<td>-57.01</td>
</tr>
</tbody>
</table>

The simulated return loss curve for different L1 and L3 is shown in figure 6. It is clear that these parameter affects the performance of the antenna. The optimum value of (W, L1, L3) is (27, 11.7, 7.2) mm. The impedance bandwidth along with return loss for different dimensions are summarized in table 3.

![Figure 6: Simulated return loss of the proposed antenna with different dimension of L1, L3 and W = 27 mm](image)

Table 3: The simulated bandwidths and return loss for various L1, L3, W=27 mm

<table>
<thead>
<tr>
<th>L1 (mm)</th>
<th>L3 (mm)</th>
<th>f1 (GHz)</th>
<th>f2 (GHz)</th>
<th>Bandwidth (%)</th>
<th>Return loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.2</td>
<td>8.2</td>
<td>1.271</td>
<td>2.9</td>
<td>78.11%</td>
<td>-55.83</td>
</tr>
<tr>
<td>8.2</td>
<td>7.2</td>
<td>1.518</td>
<td>2.912</td>
<td>62.93%</td>
<td>-45.68</td>
</tr>
<tr>
<td>11.7</td>
<td>7.2</td>
<td>1.251</td>
<td>2.884</td>
<td>77.70%</td>
<td>-64.42</td>
</tr>
</tbody>
</table>

The simulated return loss curve for W=28 mm and different dimension of L1, L3 is shown in figure 7 and the optimum value for (W, L1, L3) mm is (28, 7.2, 8.2) mm. The impedance bandwidth for different dimensions of L1, L3 are summarized in table 4.

![Figure 7: Simulated return loss of proposed antenna with different dimension of L1, L3 and W=27 mm](image)

Table 4: The simulated bandwidth and return loss for different L1, L3

<table>
<thead>
<tr>
<th>L1 (mm)</th>
<th>L3 (mm)</th>
<th>f1 (GHz)</th>
<th>f2 (GHz)</th>
<th>Bandwidth (%)</th>
<th>Return loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>7.2</td>
<td>1.541</td>
<td>3</td>
<td>64.25%</td>
<td>-46.11</td>
</tr>
<tr>
<td>8.2</td>
<td>5.2</td>
<td>1.673</td>
<td>2.872</td>
<td>52.76%</td>
<td>-40.16</td>
</tr>
<tr>
<td>7.2</td>
<td>8.2</td>
<td>1.267</td>
<td>2.921</td>
<td>78.98%</td>
<td>-54.73</td>
</tr>
</tbody>
</table>

Now, we have introduce the combine affect of dimensional parameters W, L1, L3. The variations in W, L1, L3 their respective bandwidth and return loss are summarized in table 5.

![Figure 8: Simulated return loss of proposed antenna with different dimension of L1, L2 and L3](image)

Table 5: The variation in W, L1, L2 and their respective impedance bandwith and return loss (dB)

<table>
<thead>
<tr>
<th>L1 (mm)</th>
<th>L2 (mm)</th>
<th>L3 (mm)</th>
<th>f1 (GHz)</th>
<th>f2 (GHz)</th>
<th>Band-width (%)</th>
<th>Return loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.2</td>
<td>12.2</td>
<td>7.2</td>
<td>1.273</td>
<td>2.896</td>
<td>77.86%</td>
<td>-57.01</td>
</tr>
<tr>
<td>27</td>
<td>11.7</td>
<td>7.2</td>
<td>1.271</td>
<td>2.884</td>
<td>77.70%</td>
<td>-64.42</td>
</tr>
<tr>
<td>28</td>
<td>7.2</td>
<td>8.2</td>
<td>1.267</td>
<td>2.921</td>
<td>78.98%</td>
<td>-54.73</td>
</tr>
<tr>
<td>29</td>
<td>16.7</td>
<td>8.2</td>
<td>1.313</td>
<td>2.864</td>
<td>74.26%</td>
<td>-53.12</td>
</tr>
</tbody>
</table>

The optimum value of (W, L1, L3) is (27, 11.7, 7.2) mm. The comparison of simulated impedance bandwidth versus return loss of these different parameters is shown below in figure 8.
5. Conclusion

In this paper, a comprehensive parametric study has been carried out to understand the effects of various dimensional parameters and to optimize the performance of the final proposed antenna design. After the simulation, the proposed Microstrip patch antenna occupies 1.27 GHz - 2.884 GHz frequency band. The proposed antenna structure results enhanced bandwidth of 77.70% at -10 dB return loss. The -10 dB return loss is also minimized to -64.42 dB and antenna resonates at 2.156 GHz. The proposed antenna also attains a good amount of gain i.e. 4.02129 dBi, directivity of 4.02129 dBi, antenna efficiency of 100% and radiation efficiency of 100%.

References


Author Profile

Ms. Kratika Tiwari is a M. Tech. Scholar in S R Group of Institutions, Jhansi, India in Electronics and Communication Engineering. She has specialization in communication field. Her current area of research includes MSA for wide band and ultra-wide band applications.

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