High Gain Semi-circular Patch Antenna Array Resonating in WLAN Band for Wireless Power Transmission

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Abstract - The paper presents a 1×3 semicircular patch antenna array with enhanced gain for WLAN applications. A bilayer circular patch antenna with U and half U shaped slots is optimized for high gain and then incorporated in a 1×3 array. The bilayer patch antenna has a gain around 6.50dBi. When incorporated in the array the gain is enhanced to around 7dB. The coaxial feed is used to excite the antenna. HFSS is used for the simulation.

Keywords: Antenna, Antenna array, WPT- Wireless Power Transmission, HFSS-High Frequency Structure Simulator

1. INTRODUCTION

With the world getting more and more dependent on electronic gadgets, wireless technology is gaining the spotlight. It has become a necessity for the researchers to look for alternatives to wires. The technology called Wireless Power Transmission has been in the limelight since long but has gained more importance than ever because of these new trends.

Antennas play a significant role in WPT technology. Antennas can be optimized to get a better gain performance. Higher the directivity higher the coverage area [1]. An array of antennas can help achieve even higher coverage area. Microstrip patch antennas are very useful for short-range power transmission. They are low in cost, are mechanically rugged, light weight, have low profile and are easy to fabricate. These attributes make them quite popular and appropriate for many applications such as aircraft, spacecraft, satellite applications and commercial applications like mobile radio and wireless communication [2]. Patch antennas have some limitations too viz. low efficiency, low power, high Q (sometimes in excess of 100), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth [2]. The bandwidth of patch antenna can be enhanced by increasing the thickness of the substrate and by stacking. Stacking also leads to dual band characteristics [3,4]. The U slot enhances the bandwidth and makes the patch compact [5]. It has been found that introduction of reactive elements like stubs, shorting pins and slots in the patch antenna introduces dual band characteristics in the antenna [6]. In the proposed design the aforementioned techniques namely stacking and increasing substrate thickness have been practiced to have a broader bandwidth. Parametric study has been done by modifying the radius of the semicircular patch and the coaxial feed point. It has been observed that modifying the radius modifies the resonant frequency. The feed point location affects the antenna gain and return loss. When the feed point was shifted closer to the centre of the patch, the return loss came out to be higher. Same observation was made when the feed point was shifted farther from the centre of the patch. A particular location on the x-axis resulted in the best return loss vs frequency plot. Various designs were produced to obtain a higher gain antenna and increased bandwidth in comparison with an ordinary patch antenna.

2. ANTENNA DESIGN

The patch antenna design presented in this paper is intended for a high gain and a high bandwidth. Various methods have been studied to achieve the aforementioned characteristics. Two techniques namely stacking and cutting out slots have been used in the designs.

2.1. Bilayer Circular Patch Antenna Design

The proposed design consists of two layers of substrate of same material of different thicknesses. The material chosen for the substrate is Rogers RT/duroid (tm) which has a permittivity, εr, of 2.2 and a loss tangent of 0.0009. The first layer of substrate sits on the ground and has a uniform thickness of 6mm [7]. The semicircular patch sits on the grounded substrate with half-U shaped slots cut through it. The second layer of substrate has a thickness of 5mm [7]. The circular patch which makes the second patch is installed with U shaped slots and is seated on the second layer of the substrate. Coaxial feeding technique has been preferred as it has less spurious radiations [8]. The dimensions of the slot and the feed location has been shown in Figure 1. The figure also shows the top view of the proposed design. The feed location is shown by the coordinates x_o,y_o. The side view of the design is shown in Figure 2. Table I shows the design parameters.
2.2. Discussion

The feed points were shifted and the best results were found at the feed point \( x_0, y_0, z_0 = 6, 0, 0 \). The return loss value, that came out to be \(-14.3696\, \text{dB}\), was observed to be the most acceptable when the feed was provided at this location. This also suggests that there is fine matching at the frequency below \(-10\, \text{dB}\) region. The antenna is found to resonate at the frequency 5.6600\,\text{GHz}. The bandwidth of the antenna comes out to be high i.e around 190\,\text{MHz}. The return loss vs frequency plot is shown in Figure 3. An increase in the patch radius resulted in a decrease in the resonant frequency. The patch with a radius equal to 9mm gave the best results in terms of gain and return loss. The gain of the proposed design comes out to be around 7\,\text{dB}. The radiation pattern is shown in Figure 4.

2.3. The Semicircular Patch Antenna Array

This design was incorporated in a 1×3 array in which three semicircular patches were embedded on the grounded substrate with a distance of 6\,\text{mm} between the patches. The substrate material was chosen as Rogers RT/duroid 5880.
The distance between the patches was 6mm. The feed was provided to the patch at the centre. A half U shaped slot was cut through the semicircular patch. The dimensions of the patch and the slots are given in Table II. The design of the array is shown in Figure 5.

### Table II. Dimensions for 1×3 circular patch antenna array design

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch radius</td>
<td>9 mm</td>
</tr>
<tr>
<td>Feed location (x,y,z)</td>
<td>6,0,0</td>
</tr>
<tr>
<td>Length of the slot</td>
<td>16 mm</td>
</tr>
<tr>
<td>Width of the slot</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Length of the notch</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Width of the notch</td>
<td>0.65 mm</td>
</tr>
<tr>
<td>Thickness of grounded substrate</td>
<td>6 mm</td>
</tr>
</tbody>
</table>

The semicircular patch antenna array design is based on the design of the bilayer patch antenna with U and half U shaped slots as the antenna design gave a high gain. The array shows good return loss vs frequency characteristics and this suggests that there is good matching at the frequency point below -10dB. The S11 characteristics show that the return loss is -20.7676dB at the frequency 4.900GHz. The bandwidth of the array comes out to be high i.e. approximately 400MHz. Also the array is a dual band antenna as it gives good matching below -10dB at two different frequencies. Table 3 shows the comparison of results of the bilayer circular patch antenna design and the semicircular patch antenna array.

### 3. COMPARISION OF SIMULATION RESULTS

The results show that the semicircular patch antenna array has a gain slightly higher than the bilayer circular patch antenna itself. The array also gives a better matching at 4.9GHz below -10 dB as the return loss value is lower i.e. -20.7676 dB. The bandwidth of the array comes out to be high i.e. approximately 400MHz. Also the array is a dual band antenna as it gives good matching below -10dB at two different frequencies. Table 3 shows the comparison of results of the bilayer circular patch antenna design and the semicircular patch antenna array.
Table 3: Comparison of results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bilayer Circular Patch Antenna</th>
<th>Semicircular Patch Antenna Array</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>~7dB</td>
<td>&gt;7dB</td>
</tr>
<tr>
<td>Return Loss</td>
<td>-14.3696dB</td>
<td>-20.7676dB</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>~190MHz</td>
<td>~400MHz</td>
</tr>
</tbody>
</table>

The table suggests that the model, incorporated in an array, can result in higher gain in WLAN band. When a comparison is made between the two designs, it is found that the array can help achieve higher directivity and hence coverage area for wireless transmission of power.

4. CONCLUSION AND FUTURE SCOPE

The bilayer circular patch antenna shows a high gain of around 7dB which shows that the antenna has a higher coverage area. When incorporated in the 1x3 array the gain is slightly increased. The bandwidth of the semicircular patch antenna array is higher. The array can be used to achieve a higher range of transmission of power. As gain is directly related with coverage distance, more radiating elements can be incorporated in the array to have higher gain and hence coverage distance. A series of such arrays can further increase this range. This design is very useful WLAN applications.

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REFERENCES