Narrowband Microstrip Patch Antenna Miniaturization for Wireless Applications using Split Ring Shaped Slots
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Abstract—Combining the antenna miniaturization and bandwidth preservation could increase the challenges of integrating the smaller, thinner, low profile, high efficient antennas into equipment for different applications. In this paper, we propose a new Microstrip Patch Antenna with reduced size for wireless application. We introduced Split Ring shaped slots in the patch, and found that the configuration stepped up the miniaturization by 62%. The design and analysis of the proposed antenna was carried out using Ansoft HFSS.

Key words: HFSS, Microstrip Patch, Antenna

I. INTRODUCTION
Over the last century, many researchers have germinated a dozens of versions in patch shape, feeding techniques, substrate configurations and array geometries [1-6], that surmounted its application. In the past, the method of analysis for Microstrip antennas using transmission line model [1], cavity model [2], and full wave analysis [3] has been studied. It may be desirable to model single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling using full wave analysis. Approximate formulas for input resistance, bandwidth and radiation efficiency of rectangular Microstrip antennas are derived in [4]. These formulas expect thin substrate as it involves approximations of a rigorous Sommerfeld solution. Later, broader bandwidth patch antennas were developed using proper matching networks [5], thick substrates [6] and parasitic loading [7]. The technique to assign separate frequency bands to each patch antenna was conceived and adopted to develop dual frequency patch antenna [8]. Multi-functional mobile antennas aimed at realizing multiple functional characteristics that include multi polarization antenna structure, efficient radiation characteristics with single feed arrangement became increasingly popular for indoor and outdoor wireless communication applications. Presently, high performance, smaller and light-weight compact antennas is receiving a considerable amount of attention for different types of wireless systems. Several designs were developed with the objective to reduce the size of the antenna. These include resistive loading [9] and meander-line [10] loading of the patch antenna, Frequency selective structures [11], and Electromagnetic band-gap structures [12]. These structures produce a tradeoff between the physical size of the antenna and its bandwidth. In lieu metamaterials can be used to reduce antenna size while simultaneously operating over a broader bandwidth.

In the remainder of this paper, we investigate the performance of metamaterial loaded Microstrip patch antenna for Wi-Fi application. First we design a Microstrip patch antenna operating at 2.4GHz frequency and demonstrate that by introducing split ring shaped slots the physical size of the antenna can be reduced. Details of the results are presented below.

II. CONVENTIONAL ANTENNA DESIGN
In this article, antenna miniaturization was realized at 2.4 GHz Wi-Fi frequency band.

Fig. 1: Rectangular Patch Antennas Resonating At 2.4ghz.
Fig. 1 depicts patch antennas etched on same substrate with $\varepsilon_r=4.4$ and the co-axial feeding technique were applied to feed the antennas. The first antenna resonates at 2.4GHz. An arbitrary small sized antenna was taken to study the effect of reduced antenna size on resonant frequency.

The antenna dimensions, material properties and operating frequency details are shown in Table.1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Patch 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonant Frequency</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>Patch dimension</td>
<td>28.45 x 36.5mm</td>
</tr>
<tr>
<td>Substrate</td>
<td>FR4 epoxy</td>
</tr>
<tr>
<td>Substrate Thickness</td>
<td>1.57mm</td>
</tr>
</tbody>
</table>

Table 1: Antenna Specification

Fig. 2: Return Loss Plot for Rectangular Patch Antenna
As shown in Fig.2, patch with dimension 28.45mm x 36.5mm resonates at 2.4GHz. The objective of this article is to shift the resonating frequency down from 2.4GHz maintaining dimensions of patch to achieve miniaturization.

III. NOVEL DESIGN FOR ANTENNA MINIATURIZATION

The cost of antenna miniaturization was limited by its wavelength dependence [7]. While the capacitive elements decrease the bandwidth, it only promises goals for miniaturization. But inductive elements are restricted to low frequency; the certainty of miniaturization is more than under conventional techniques in giga-hertz frequency range.

There are out-of-plane designs having SRRs deliberately introduced to the patch geometry that showed potential for miniaturization. However, such structures are non-optimal and fabrication process would be difficult.

![3D View Of A Rectangular Patch Antenna And SRR Simulated Using HFSS](image)

The simulated patch antenna and the setup are shown in Fig.3, where the two Split Ring shaped slots were made in the patch antenna. The dimension of the rings was optimized to get the lowest resonant frequency with good return loss.

IV. SIMULATION RESULTS AND DISCUSSION

The antennas were designed using HFSS and the simulated return loss depicting the potential for miniaturization is shown in Fig. 4 below.

![Return Loss Plot Depicting Reduction In Resonant Frequency With The Introduction Of Split Ring Shaped Slot](image)

The shift in the resonant frequency of the antenna, as depicted in Fig.4, largely depends on the dimension of Split Ring Shaped slot in the bottom of the patch. With the introduction of one more Split Ring shaped slot in the top of the patch, the return loss decreased to -23dB at 1.5GHz. Hence, in this design, 62% diminution in antenna size was attained.

The summary of the simulation is shown in Table 2.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Patch without Split Ring shaped Slot</th>
<th>Patch with Split Ring Shaped Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.4GHz</td>
<td>1.52 GHz</td>
</tr>
<tr>
<td>Patch Size</td>
<td>28.45 x 36.5 x 0.1</td>
<td>46.17 x 59.27 x 0.1</td>
</tr>
<tr>
<td>S11 in dB</td>
<td>-31.4 dB</td>
<td>-23 dB</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>70 MHz</td>
<td>20 MHz</td>
</tr>
</tbody>
</table>

Table 2: Simulation Results Summary

As seen from Table. II when split ring shaped slots are made on the patch the resonant frequency scale down to 1.52GHz. The actual size of the patch required to resonate at this frequency is 46.17mm x 59.27mm thereby achieving 62% reduction in size.

V. CONCLUSION

In this paper, we presented our results on Microstrip Patch Antenna by incorporating Split Ring shaped slots on the patch. The objective of scaling down the resonant frequency of patch antenna from 2.4GHz maintaining the dimension of the patch was discussed highlighting the benefits of it. We performed simulation for patch antenna with and without Split Ring shaped slots and attained 62% physical size reduction. Next time, we plan to fabricate the designed antennas and validate the simulation results.

REFERENCES


