This paper reports experimental investigations on suspended microstrip rectangular patch antennas at X-band with dielectric resonator loading. By placing the resonator at appropriate position on the patch, an impedance bandwidth of about 12.3% and an improvement in gain over the unloaded case by about 1 to 2 dB have been achieved, without much change in the radiation pattern.

Introduction

Microstrip patch antennas are well known for their advantages in terms of small weight, low profile and ease of manufacture. However, the main limiting factor in implementing these antennas in many applications is their low impedance bandwidth (typically 2-3%). One popularly used technique of enhancing the bandwidth is to use multi-layered microstrip[1,2]. The most widely accepted structure in this category is the suspended microstrip, which, in view of the air layer next to the ground plane, offers improved efficiency. Recently George et al [3] have reported enhanced bandwidth in a rectangular microstrip patch antenna by loading it with a ceramic dielectric resonator (DR). There is as yet no literature that reports the combined advantages of suspended microstrip and dielectric resonator loading. The aim of this paper is to study the bandwidth and radiation characteristics of suspended microstrip rectangular patch antennas with dielectric resonator loading.

Design and Experiment

Figure 1 shows the geometry of a suspended microstrip rectangular patch antenna with dielectric resonator loading. The cross section of the suspended microstrip and the layout of the patch antenna are shown separately. The suspended microstrip uses a substrate (GML1000) of thickness \(d = 0.508\) mm and relative dielectric constant \(\varepsilon_r = 3.05\). The air gap between the substrate and the ground plane is \(a = 0.25\) mm. The rectangular patch antenna has a length \(L\) and width \(W\) and it uses a recessed feed. A cylindrical dielectric resonator (DR) of diameter \(D\), height \(H\) and relative dielectric constant \(\varepsilon_{dr}\) is used for loading the antenna.

Keeping the suspended microstrip parameters \(d, \varepsilon_r\), and \(a\) fixed, several patch antennas were designed corresponding to different resonant frequencies in the range 9 to 11 GHz. The resonant length of the patch was calculated using the standard formula,
\[ L = \frac{v_0}{2f_0 \sqrt{\varepsilon_{\text{eff}}}} - 2\Delta \]  

(1)

where \( \varepsilon_{\text{eff}} \) is the effective dielectric constant of the suspended microstrip, \( f_0 \) is the resonant frequency of the antenna, \( v_0 \) is the free space velocity and \( \Delta \) is the end correction. The expression for end correction is given by [4]

\[ \frac{\Delta}{h} = 0.412 \left( \frac{\varepsilon_{\text{eff}} + 0.3}{\varepsilon_{\text{eff}} - 0.258} \right) \left( \frac{w}{h} + 0.262 \right) \left( \frac{w}{h} + 0.813 \right) \]  

(2)

where \( h = (a+d) \) is the height of the patch above the ground plane.

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**Fig. 1** Geometry of dielectric resonator loaded suspended microstrip antenna

(a) layout of patch showing position of resonator  
(b) cross section of suspended microstrip

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The resonant frequencies were measured for several antennas designed as per the above formulas. The measured resonant frequencies were slightly lower than the theoretical values. The experimentally deduced end correction was then utilized to redesign and fabricate the antennas.

For loading the antennas, two different cylindrical dielectric resonators (from Trans-Tech) were chosen. Their dimensions and resonant frequencies (\( f_{dr} \)) are as follows:
Dielectric Resonator 1 (DR1) : $D = 5 \text{ mm}, H = 3.1 \text{ mm}, f_{dr} = 10.26 \text{ GHz}$  
Dielectric Resonator 2 (DR2) : $D = 5 \text{ mm}, H = 3.37 \text{ mm}, f_{dr} = 10 \text{ GHz}$

Return loss and impedance characteristics were studied by taking measurements on a Network Analyzer for several patch antennas both with and without the resonator loading. For all the antennas, the optimum position that gave the maximum return loss bandwidth was found to be around the right corner of the radiating edge away from the feeder (as illustrated in Fig. 1a). Radiation pattern measurements were also made on the antennas with and without the resonator loading in both the E- and H- planes.

Results

An improved bandwidth in the range 11–12.3 % was achieved with dielectric resonator loading of the antennas, in place of 5-6% bandwidth for the same antennas without loading. The Table below presents a typical set of experimental results for a suspended microstrip rectangular patch antenna loaded with each of the two resonators (DR1 and DR2). Figure 2 shows measured E- and H- plane patterns of the antenna loaded with DR1. The readings without the resonator are superposed on the same graph.

Table

<table>
<thead>
<tr>
<th>Antenna loaded with</th>
<th>Resonant freq. (GHz)</th>
<th>10 dB Return loss bandwidth (GHz)</th>
<th>Bandwidth (%)</th>
<th>3 dB Beamwidth E-plane</th>
<th>3 dB Beamwidth H-plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR1</td>
<td>10.26</td>
<td>1.26</td>
<td>12.3</td>
<td>55$^\circ$</td>
<td>70$^\circ$</td>
</tr>
<tr>
<td>DR2</td>
<td>9.96</td>
<td>1.09</td>
<td>11</td>
<td>55$^\circ$</td>
<td>70$^\circ$</td>
</tr>
</tbody>
</table>

As shown in the Table above, the 3dB bandwidth of the antenna remains the same with and without the resonator. In the loaded case, there is slight asymmetry in the E-plane pattern but not in the H-plane pattern. This is expected because of the asymmetric positioning of the resonator. As part of the experimentation the actual power radiated by the antenna with and without the resonator was measured. Measurements on several antennas showed an improvement of 1-2 dB in gain around the resonant frequency.

Conclusion
The impedance bandwidth of a rectangular patch antenna in suspended microstrip configuration is shown to increase by a factor of nearly two through dielectric resonator loading. With resonator loading, the gain of the antenna also improves by about 1-2 dB whereas the 3 dB beamwidths in the E- and H- planes have practically no effect.

![E-plane and H-plane patterns](image)

Fig. 2 E- and H- plane patterns of a rectangular patch antenna (L =10.18 mm, W = 11 mm) loaded with DR1 and without loading.

References

