Compact microstrip patch antenna for microwave communication

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A single layer, single feed compact rectangular microstrip antenna is proposed. Resonant frequency has been reduced drastically by cutting three unequal rectangular slots at the edge of the patch and also small rectangular slots connected with the middle of every patch. Antenna size has been reduced by 47.4% with an increased frequency ratio when compared to a conventional square microstrip patch antenna.

Keywords: Compact Patch, Slot antenna, Microwave resonant frequency patch antenna

1 Introduction

In recent years demand for small antennas in wireless communication has increased the interest of research work on compact microstrip antenna design among microwaves and wireless engineers¹. To support the high mobility necessary for a wireless telecommunication device, a small and light weight antenna is likely to be preferred. For this purpose, Compact Microstrip antenna is one of the most suitable devices. The development of antenna for wireless communication also requires an antenna with more than one operating frequency. This is mainly because there are various wireless communication systems and many telecommunication operators are using various frequencies. Therefore, one antenna that has multiband characteristic is more desirable than having one antenna for each frequency band. To reduce the size of the antenna one of the effective techniques is cutting slot in proper position on the microstrip patch²,⁵. There are so many antennas which are used to reduce the size of the antenna. Reducing the size of the antenna means the resonant frequency of slotted antenna is drastically reduced as compared to conventional antenna⁶,⁷,⁸. Other than slotted antenna, there are antennas like DRA (Dielectric Resonator Antenna), Fractal Antenna¹⁵,¹⁶,¹⁷,¹⁸ etc. Fractal antennas are difficult to design and DRA requires high dielectric constant substrates which are not readily available. Compact microstrip antenna is a topic of intensive research in recent years because of increasing demand for small antennas used in various types of communications including mobile communication⁹,¹⁰. The size of the antenna may be effectively reduced by cutting rectangular slots on printed antennas. The work to be presented in this paper is also a compact printed antenna obtained by cutting rectangular slots which gave a resonant frequency much lower than the resonant frequency of the conventional printed antenna with the same patch area. It also increase the return loss and gain-bandwidth performance of the antenna. To reduce the size of the antenna substrates are chosen with higher value of dielectric constant¹¹,¹². The antennas can withstand exposure to high temperatures when covered by a radome made of the same soft dielectric as the substrate. The cover protects the metal patches but has only a minor effect on the resonant frequency¹³,¹⁴. High temperatures on the surface of the radome or ablation fail to change the resonance significantly because the radome itself has only a minor effect. Variation in the dielectric constant of the substrate from lot-to-lot causes problems with repeatability. The narrowband antennas require measurement of the dielectric constant of each lot, and sometimes of each sheet, to get the center frequency desired. A series of etching masks can be made to cover the expected range. The antennas can be tuned with inductive shorting pins or capacitive
screws, but tuning is prohibitive when the number of elements in an array is large. Careful quality control of the dielectric constant is the answer. Close monitoring of the etching process may also be needed to prevent excessive undercutting. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. The proposed antenna (substrate with \( \varepsilon_r = 4.4 \)) presents a size reduction of 47.4% when compared to a conventional rectangular microstrip patch. The simulation has been carried out by IE3D\textsuperscript{22} software which uses the MOM method and verified by measurements. Due to the small size, low cost and light weight this antenna is a good candidate for the application of S-band microwave communication in the frequency range 2-4 GHz.

The S band is part of the microwave band of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves with frequencies that range from 2 to 4 GHz, crossing the conventional boundary between UHF and SHF at 3.0 GHz. The S band is used by weather radar, surface ship radar, and some communications satellites, especially those used by NASA to communicate with the Space Shuttle and the International Space Station. Another important application is microwave oven which works by passing non-ionizing microwave radiation through the food. Microwave radiation is between common radio and infrared frequencies, being usually at 2.95 gigahertz (GHz)—a wavelength of 122 millimeters (4.80 in).

2 Antenna Design

Different values of dielectric constant are possible for PTFE substrate. Basically, the values of dielectric constant for PTFE substrate are 2.2 and 4.4 which are readily available. There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of 2.2 \( \leq \varepsilon_r \leq 35 \). The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. Thin substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes, however, because of their greater losses; they are less efficient and have relatively smaller bandwidths. So, due to the above reason, we choose the value of dielectric constant in the paper as 4.4 and it is the correct value for designing the proposed microstrip antenna. PTFE (polytetrafluoroethylene) based substrates are used to provide a laminate with a dielectric constant that is relatively low. While PTFE has very good electrical properties, other properties need to be well understood for several considerations. The design and fabrication of microstrip patch antennas are easily possible on PTFE substrate. For MoM based transmission line analysis, we can choose any dimensions for width (W) and length (L). Now in the present paper, we chose a square substrate to design the proposed antenna whose width and length are the same. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane.

The configuration of the conventional printed antenna is shown in Fig. 1 with \( L=20 \text{ mm} \), \( W=20 \text{ mm} \), Poly tetra fluoro ethylene (PTFE) substrate thickness \( h = 1.5875 \text{ mm} \), dielectric constant \( \varepsilon_r = 4.4 \). Coaxial probe-feed (radius=0.5 mm) is located at \( W/2 \) and \( L/3 \). Assuming practical patch width \( W = 20 \text{ mm} \) for efficient radiation.

Figure 2 shows the configuration of antenna 2 designed with similar PTFE substrate. Three unequal rectangular slots (L1, L2, L3) whose dimensions and the location of coaxial probe-feed (radius=0.5 mm) are shown in Fig. 2.

3 Results and Discussion

Simulated (using IE3D [22]) results of return loss in conventional and slotted antenna structures are shown in Figs 3 and 4. A significant improvement of...
frequency reduction is achieved in antenna 2 with respect to the conventional antenna 1 structure.

In the conventional antenna, return loss of about 17.7 dB is obtained at 3.410 GHz. Corresponding 10 dB bandwidth is 53.7 MHz. The second resonant frequency is obtained at $f_2 = 6.77$ GHz. Corresponding 10 dB bandwidth is obtained for Antenna 1 at $f_2 = 202.1$ MHz.

Due to the presence of slots in antenna 2 resonant frequency operation is obtained with large values of frequency ratio. The first resonant frequency is obtained at $f_1 = 2.95$ GHz with return loss of about 13.02 dB. The second and third resonant frequency is obtained at $f_2 = 3.48$ GHz, $f_3 = 6.68$ GHz with return losses $-18.13$ dB, $-11.04$ dB, respectively. Corresponding 10 dB bandwidth is obtained for Antenna 2 at $f_1, f_2, f_3$ are 18.14 MHz, 56.72 MHz and 57.90 MHz, respectively.

The simulated E plane and H-plane radiation patterns are shown in Figs 5-14. For the antenna 1 (Conventional Antenna) radiation patterns are shown in Figs 5-8.

The simulated E plane radiation pattern of antenna 1 (Conventional Antenna) for 3.41 GHz is shown in Fig. 5.

The simulated H plane radiation pattern of antenna 1 (Conventional Antenna) for 3.41 GHz is shown in Fig. 6.

The simulated E plane radiation pattern of antenna 1 (Conventional Antenna) for 6.77 GHz is shown in Fig. 7.

The simulated H plane radiation pattern of antenna 1 (Conventional Antenna) for 6.77 GHz is shown in Fig. 8.
Fig. 5 — E-plane radiation pattern for antenna 1 at 3.41 GHz

Fig. 6 — H-plane radiation pattern for antenna 1 at 3.41 GHz

Fig. 7 — E-plane radiation pattern for antenna 1 at 6.77 GHz

Fig. 8 — H-plane radiation pattern for antenna 1 at 6.77 GHz

Fig. 9 — E-plane radiation pattern for antenna 2 at 2.95 GHz

Fig. 10 — H-plane radiation pattern for antenna 2 at 2.95 GHz
Fig. 11 — E-plane radiation pattern for antenna 2 at 3.48 GHz

Fig. 12 — H-plane radiation pattern for antenna 2 at 3.48 GHz

Fig. 13 — E-plane radiation pattern for antenna 2 at 6.68 GHz

Fig. 14 — H-plane radiation pattern for antenna 2 at 6.68 GHz

Fig. 15 — VSWR versus frequency plot for proposed antenna

The simulated E plane radiation pattern of antenna 2 (Slotted Antenna) for 2.95 GHz is shown in Fig. 9.

The simulated H plane radiation pattern of antenna 2 (Slotted Antenna) for 2.95 GHz is shown in Fig. 10.

The simulated E plane radiation pattern of antenna 2 (Slotted Antenna) for 3.48 GHz is shown in Fig. 11.

The simulated H plane radiation pattern of antenna 2 (Slotted Antenna) for 3.48 GHz is shown in Fig. 12.

The simulated E plane radiation pattern of antenna 2 (Slotted Antenna) for 6.68 GHz is shown in Fig. 13.

The simulated H plane radiation pattern of antenna 2 (Slotted Antenna) for 6.68 GHz is shown in Fig. 14.

The simulated E plane VSWR versus frequency plot of proposed antenna is shown in Fig. 15. The VSWR value for the 1st resonant frequency (2.95 GHz) is 1.58. The second and third resonant frequency is obtained at $f_2 = 3.48$ GHz, $f_3 = 6.68$ GHz.
with VSWR value 1.33 and 1.78, respectively. These all values are within 2:1 range.

All the simulated results are summarized in the following Tables 1 and 2.

The prototype of the Antenna 1 (Conventional Antenna) and Antenna 2 (Proposed Antenna) was fabricated and tested, which are shown in Figs 16-21. All the measurements were carried out using Vector Network Analyzer (VNA) Agilent N5 230A.

The comparisons of the measured return loss with the simulated ones are shown in Fig.20 (for conventional antenna) and Fig. 21 (for Proposed

### Table 1 — Simulated results for antenna 1 and 2 with respect to radiation pattern

<table>
<thead>
<tr>
<th>Antenna structure</th>
<th>Resonant freq. (GHz)</th>
<th>Freq. ratio</th>
<th>3 DB beam width (°)</th>
<th>Absolute gain (DBI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>f_1 = 3.41</td>
<td>f_2/f_1 = 1.985</td>
<td>171.06°</td>
<td>5.43</td>
</tr>
<tr>
<td></td>
<td>f_2 = 6.77</td>
<td></td>
<td>170.40°</td>
<td>3.23</td>
</tr>
<tr>
<td>2</td>
<td>f_1 = 2.95</td>
<td>f_2/f_1 = 1.180</td>
<td>152.3°</td>
<td>4.79</td>
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<tr>
<td></td>
<td>f_2 = 3.48</td>
<td></td>
<td>156.9°</td>
<td>5.44</td>
</tr>
<tr>
<td></td>
<td>f_3 = 6.68</td>
<td>f_3/f_1 = 2.264</td>
<td>171.2°</td>
<td>4.09</td>
</tr>
</tbody>
</table>

### Table 2 — Simulated results for antenna 1 and 2 with respect to return loss

<table>
<thead>
<tr>
<th>Antenna structure</th>
<th>Resonant frequency (GHz)</th>
<th>Return loss (DB)</th>
<th>10 DB bandwidth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>f_1 = 3.41</td>
<td>-17.7</td>
<td>53.7</td>
</tr>
<tr>
<td></td>
<td>f_2 = 6.77</td>
<td>-23.7</td>
<td>202.1</td>
</tr>
<tr>
<td>2</td>
<td>f_1 = 2.95</td>
<td>-13.02</td>
<td>18.14</td>
</tr>
<tr>
<td></td>
<td>f_2 = 3.48</td>
<td>-18.13</td>
<td>56.72</td>
</tr>
<tr>
<td></td>
<td>f_3 = 6.68</td>
<td>-11.04</td>
<td>57.9</td>
</tr>
</tbody>
</table>
Antenna). The discrepancy between the measured and simulated results is due to the effect of improper soldering of SMA connector or fabrication tolerance.

4 Conclusions

Theoretical investigations of a single layer single feed micro strip printed antennas have been carried out using Method of Moment based software IE3D which was verified by measurements with the help of VNA (Vector Network Analyzer). Introducing slots at the edge of the patch size reduction of about 47.4% have been achieved. The 3dB beam-width of the radiation pattern 152.3° which is sufficiently broad beam for the applications for which it is intended. The resonant frequency antenna presented in the paper for a particular location of feed point (3 mm, 2 mm) considering the centre as the origin) was quite large as is evident from Table 1. Alteration of the location of the feed point results in narrower 10 dB bandwidth and less sharp resonances.

Fig. 20 — Comparison between simulated and measured data for conventional antenna

Fig. 21 — Comparison between simulated and measured data for proposed antenna
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References