Multi-Band Microstrip Slotted Patch Antenna for Application in Microwave Communication

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Abstract—A single layer, single feed compact slotted patch antenna is thoroughly simulated in this paper. Resonant frequency has been reduced drastically by cutting two equal slots which are the combinations of one triangular and another rectangular slot at the upper right and lower left corner from the conventional microstrip patch antenna. Simulated antenna size has been reduced by 48.89% with an increased frequency ratio when compared to a Conventional microstrip patch antenna.

Keywords— Compact, Patch, Slot, Resonant frequency, Bandwidth.

I. INTRODUCTION

In recent years, demand for small antennas on wireless communication has increased the interest of research work on compact microstrip antenna design among microwave and wireless engineers [1-6]. To support the high mobility necessity for a wireless telecommunication device and for high resolution mapping for radar communication, a small and light weight compact microstrip antenna is one of the most suitable application. The development of antenna for wireless communication also requires an antenna with more than one operating frequency. This is due to many reasons, primarily because of various wireless communication systems and many telecommunication operators use various frequencies. Therefore one antenna that has multiband characteristic is more desirable than having one antenna for each frequency band. Most effective technique is cutting slot in proper position on the microstrip patch. In this paper includes cutting two equal slots which are the combinations of one triangular and rectangular slot at the upper right and lower left corner from the conventional microstrip patch antenna, to increase the return loss and gain-bandwidth performance of the simulated antenna (Figure 2). To reduce the size of the antenna substrates are chosen with higher value of dielectric constant [7-10]. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth.

The proposed antenna (substrate with \( \varepsilon_r = 4.4 \)) has a gain of 3.24 dBi and presents a size reduction of 48.89% when compared to a conventional microstrip patch (10mm X 6mm). The simulation has been carried out by IE3D [11] software which uses the MOM method. Due to the small size, low cost and low weight this antenna is a good entrant for the application of X-Band microwave communication and Ku-Band RADAR communication.

The X band belongs to in the microwave radio region of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 8.0 to 12.0 GHz. The X band is used for short range tracking, missile guidance, marine, radar and airborne intercept. Especially, it is used for radar communication ranges roughly from 8.29 GHz to 11.4 GHz. The Ku-Band belongs to in the microwave radio region of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 12.0 to 18.0 GHz. The Ku band is used for high resolution mapping and satellite altimetry. Specially, Ku Band is used for tracking the satellite within the ranges roughly from 12.87 GHz to 14.45 GHz.

II. ANTENNA DESIGN

The configuration of the conventional printed antenna is shown in Figure 1 with \( L=6 \text{ mm}, W=10 \text{ mm}, \) substrate (PTFE) thickness \( h = 1.6 \text{ mm}, \) dielectric constant \( \varepsilon_r = 4.4, \) Coaxial probe-feed (radius=0.5mm) is located at W/2 and L/3.

Assuming practical patch width \( W= 10 \text{ mm} \) for efficient radiation and using the equation [6],

\[
\begin{align*}
\text{fr} &= \frac{c}{2W} \times \sqrt{\frac{2}{(1+\varepsilon)\sqrt{1+\varepsilon}}} \quad \ldots 1
\end{align*}
\]
Where, $c =$ velocity of light in free space. Using the following equation [9] we have determined the practical length $L=6$ mm.

\[ L = L_{\text{eff}} - 2\Delta L \quad \ldots 2 \]

where,

\[ \frac{\Delta L}{h} = 0.412 \times \left( \frac{E_{\text{eff}}+0.3)(W/h+0.264)}{(E_{\text{eff}}-0.258)(W/h+0.8)} \right) \quad \ldots 3 \]

\[ E_{\text{eff}} = \left( \frac{E_r+1}{2} + \frac{E_r-1}{2 \times \left( 1+\frac{h}{W} \right)^2} \right) \quad \ldots 4, \]

and

\[ L_{\text{eff}} = \left[ \frac{c}{2 \times \left( 1 + \frac{h}{W} \right)^2 \sqrt{E_{\text{eff}}}} \right] \quad \ldots 5 \]

Where, $L_{\text{eff}} =$ Effective length of the patch,

$\Delta L/h =$ Normalized extension of the patch length,

$E_{\text{eff}} =$ Effective dielectric constant.

Figure 1: Conventional Antenna configuration

Figure 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. Two equal slots which are the combinations of one triangular and rectangular slot at the upper right and lower left corner and the location of coaxial probe-feed (radius=0.5 mm) are shown in the figure 2.

Figure 2: Simulated Antenna configuration

III. RESULTS AND DISCUSSION

Simulated (using IE3D [10]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved with simulated antenna compared to its conventional antenna counterpart.

Figure 3: Antenna 1 Return Loss vs. Frequency (Conventional Antenna)
In conventional antenna, return loss of about -7.0 dB is obtained at 13.39 GHz. Comparative analysis of Fig.3 & 4 depicts that for the conventional antenna (fig.3), there is practically no resonant frequency at around 9.89 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 9.89 GHz with the return loss as high as -24.9 dB.

Due to the presence of slots in simulated antenna resonant frequency operation is obtained with large values of frequency ratio. The first and second resonant frequency is obtained at \( f_1 = 9.88 \) GHz with return loss of about -24.94 dB and at \( f_2 = 13.62 \) GHz with return losses -30.66 dB respectively. Corresponding 10 dB bandwidth is obtained for Antenna 2 at \( f_1 \) and \( f_2 \) are 787.57 MHz and 1.42 GHz, respectively.

The simulated E plane and H-plane radiation patterns are shown in Figure 5-12. The simulated E plane radiation pattern of simulated antenna for 9.88 GHz is shown in figure 5.

The simulated H plane radiation pattern (3D-view) of slotted antenna for 9.88 GHz is shown in figure 6.

The simulated H plane radiation pattern (3D-view) of slotted antenna for 9.88 GHz is shown in figure 8.
The simulated E plane radiation pattern of slotted antenna for 13.62 GHz is shown in figure 9.

The simulated H plane radiation pattern of slotted antenna for 13.62 GHz is shown in figure 10.

The simulated H plane radiation pattern of slotted antenna (3D-view) for 13.62 GHz is shown in figure 11.

The simulated H plane radiation pattern of slotted antenna (3D-view) for 13.62 GHz is shown in figure 12.
All the simulated results are summarized in the following Table1 and Table2.

**TABLE I: SIMULATED RESULTS FOR ANTENNA 1 AND 2**

<table>
<thead>
<tr>
<th>ANTENNA STRUCTURE</th>
<th>RESONANT FREQUENCY (GHz)</th>
<th>RETURN LOSS (dB)</th>
<th>10 DB BANDWIDTH (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>f₁= 13.39</td>
<td>-7.00</td>
<td>NA</td>
</tr>
<tr>
<td>Slotted</td>
<td>f₁= 9.88</td>
<td>-24.94</td>
<td>0.7875</td>
</tr>
<tr>
<td></td>
<td>f₂= 13.62</td>
<td>-30.66</td>
<td>1.4201</td>
</tr>
</tbody>
</table>

**TABLE II: SIMULATED RESULTS FOR ANTENNA 1 AND 2**

<table>
<thead>
<tr>
<th>ANTENNA STRUCTURE</th>
<th>RESONANT FREQUENCY (GHz)</th>
<th>3 DB BEAM-WIDTH (°)</th>
<th>ABSOLUTE GAIN (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>f₁= 13.39</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Slotted</td>
<td>f₁= 9.88</td>
<td>161.53°</td>
<td>3.24</td>
</tr>
<tr>
<td></td>
<td>f₂= 13.62</td>
<td>55.51°</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Frequency Ratio for Slotted Antenna**

f₂/ f₁ = 1.379

IV. CONCLUSION

Detailed simulation studies of a single layer single feed microstrip printed antenna have been carried out using Method of Moment based software IE3D. Introducing slots at the edge of the patch size reduction of about 48.89% has been achieved. The 3dB beam-width of the radiation pattern 161.53° which is sufficiently broad beam for the applications for which it is intended.

The resonant frequency of slotted antenna, presented in the paper, designed for a particular location of feed point (4mm, 2.5mm) considering the centre as the origin is quite large as evident from the above analysis. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances.

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