HEXAGONAL MICROSTRIP PRINTED ANTENNA DESIGN AND ANALYSIS OF GAIN FOR KU- BAND APPLICATIONS

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ABSTRACT

The Microstrip patch antenna is one of the most preferred antenna structures for low cost, light weight and compact design for microwave application, wireless systems & RF application. In this paper low gain of hexagonal microstrip printed antenna is one of the applications of Ku-band. These antennas are of a relative interest since they can support multiple communication systems. The radiating elements in this antenna are composed of two triangular and one rectangular slot from the conventional microstrip patch antenna. These slots are engraved in the rectangular and triangular patch, joined together in four structures with a center point Y shaped. The theoretical analysis is based on the Zeland IE3D software. The measurement parameters satisfy required limits hence making the proposed antenna suitable for Ku-band applications. Results of the designed and simulated antenna size have been reduced by 11.99% with an increased frequency ratio.

Keywords: Bandwidth, Compact, Gain, Patch, Resonant frequency, Slot.

I. INTRODUCTION

Recently the microstrip patch antenna is the requirement of modern communication systems highly. Because of their simplicity and compatibility with printed-circuit technology microstrip antennas are widely used in the microwave frequency spectrum. Simply a microstrip antenna is a rectangular or other shape, patch of metal on top of a grounded dielectric substrate. Microstrip patch antennas [1-5] are attractive in antenna applications for many reasons. They are easy and cheap to manufacture, lightweight, and planar to list just a few advantages. Also they can be manufactured either as a stand-alone element or as part of an array. However, these advantages are offset by low efficiency and limited bandwidth. In recent years much research and testing has been done to increase both the bandwidth and radiation efficiency of microstrip antennas.
Due to the recent interest in broadband antennas a microstrip patch antenna was developed to meet the need for a cheap, low profile, broadband antenna [6-7]. This antenna could be used in a wide range of applications such as in the communications industry for cell phones [8] or satellite communication and any other microwave application [12-18].

Microstrip patch antennas have many advantages over conventional antennas which makes them suitable for a wide variety of applications. However, a major drawback of these antennas is the low bandwidth. Various techniques have been proposed by researchers to enhance its bandwidth.

In the whole of world different standard microwave frequency bandwidth is used different designations. Particularly the use of C-Band in future will possibly certainly rather decrease than increase. At the current point of time - C Band nevertheless is widely used. In particular as Ku band capacity over some regions is quite limited [11].

Ku-band frequency range is allocated to be exclusively used by satellite communication [13] systems, thereby eliminating the problem of interference with microwave systems. Due to higher power levels at new satellites Ku-band allows for significantly smaller earth station antennas and RF units to be installed at the VSAT location. Ku Band on the other hand operates with small antennas and less expensive equipment, while the capacity price is higher than C Band.

Ku-Band [12-18GHz] is used for most satellite communication systems particularly satellite TV [16], broadcasting satellite service (BSS) [19], fixed satellite systems (FSS) [17], direct broadcasting satellite (DBS) [14]; VSAT systems; marine communications are used. Now especially spacebourne land mobile; Satellite messaging for commercial jets are used on today. Most radar band applications used in C-band but police radar has been another important application [10] in the Ku-band.

II. ANTENNA DESIGN

The configuration of the conventional printed antenna is shown in Figure 1 with L=6 mm, W=12 mm, substrate (PTFE) thickness h = 1.6 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=12 mm for efficient radiation and using the equation [6],

$$f_r = \frac{c}{2W} \times \sqrt{\frac{2}{1+\varepsilon_r}}$$

Where, $c$ = velocity of light in free space.

Using the following equation [9] we determined the practical length L (=6mm) & width W (=12mm).

$$L = L_{eff} - \frac{2\Delta L}{c}$$

$$W = \frac{c}{2f\sqrt{(\varepsilon_r + 1)/2}}$$

Where, $\frac{\Delta L}{h} = \left[0.412 \times \frac{(\varepsilon_{reff}+0.3) \times (W/h+0.264)}{(\varepsilon_{reff} - 0.258) \times (W/h+0.8)}\right]$ and $\varepsilon_{reff} = \left[\frac{(\varepsilon_r+1)}{2} + \frac{\varepsilon_r-1}{2 \times \sqrt{(1+12\times \frac{h}{W})}}\right]$.
And \[ L_{\text{eff}} = \left[ \frac{c}{2 \times f_r \times \sqrt{\varepsilon_{\text{eff}}}} \right] \]

Where, \( L_{\text{eff}} = \) Effective length of the patch, \( \Delta L/h = \) Normalized extension of the patch length, \( \varepsilon_{\text{eff}} = \) Effective dielectric constant.

Figure 1: Conventional Antenna configuration

Figure 2: Simulated Antenna configuration

Figure 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. Two equal slots which are the combinations of two triangular and a 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.
III. RESULTS AND DISCUSSION

Simulated (using IE3D [20]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved in simulated antenna with respect to the conventional antenna structure.

**Figure 3:** Return Loss vs. Frequency (Conventional Antenna)

**Figure 4:** Return Loss vs. Frequency (Slotted Antenna)

In the conventional antenna return loss of about -7.01 dB is obtained at 13.39 GHz. Comparing fig.3 and fig.4 it may be observed that for the conventional antenna (fig.3), there is practically no resonant frequency at around 12.65 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 12.6416 GHz where the return loss is as high as -24.9313 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 $f_1 = 12.6416$ GHz with return loss of about -24.9313 dB and at $f_2 = 16.7591$ GHz with return losses -12.1438 dB respectively.

Corresponding 10dB band width obtained for Antenna 2 at $f_1$, $f_2$ are 0.7945 GHz and 0.747089 GHz respectively. The simulated E plane and H-plane radiation patterns are shown in Figure 5-18. The simulated E plane & H plane radiation pattern of simulated antenna for 12.65 GHz is shown in figure 5 and figure 6.

**Figure 5:** E-Plane Radiation Pattern for Slotted Antenna at 12.65 GHz

**Figure 6:** H-Plane Radiation Pattern for slotted Antenna at 12.65 GHz
The simulated E plane and H plane radiation pattern of slotted antenna for 16.75 GHz is shown in figure 7 & figure 8.

**Figure 7:** E-Plane Radiation Pattern for slotted antenna at 16.75 GHz

**Figure 8:** H-Plane Radiation Pattern for slotted antenna at 16.75 GHz
The simulated Cartesian E-plane & H-plane radiation pattern (2D) of simulated antenna for 12.65 GHz is shown in figure 9 & figure 10

**Figure 9:** E-Plane Radiation Pattern (2D) for slotted antenna at 12.65 GHz

**Figure 10:** H-Plane Radiation Pattern (2D) for slotted antenna at 12.65 GHz
The simulated Cartesian E-plane & H-plane radiation pattern (2D) of simulated antenna for 16.75 GHz is shown in figure 11 & figure 12.

**Figure 11:** E-Plane Radiation Pattern (2D) for slotted antenna at 16.75 GHz

**Figure 12:** H-Plane Radiation Pattern (2D) for slotted antenna at 16.75 GHz
The simulated E plane & H-plane radiation pattern (3D) of simulated antenna for 12.65 GHz is shown in figure 13 & figure 14.

**Figure 13:** E-Plane Radiation Pattern (3D) for slotted antenna at 12.65 GHz

**Figure 14:** H-Plane Radiation Pattern (3D) for slotted antenna at 12.65 GHz
The simulated E plane & H-plane radiation pattern (3D) of simulated antenna for 16.75 GHz is shown in figure 15 & figure 16.

**Figure 15:** E-Plane Radiation Pattern (3D) for slotted antenna at 16.75 GHz

**Figure 16:** H-Plane Radiation Pattern (3D) for slotted antenna at 16.75 GHz
The simulated smith chart and VSWR of simulated antenna shown in figure 17 & figure 18.

**Figure 17:** Simulated Smith Chart for slotted antenna

**Figure 18:** Simulated VSWR for slotted antenna
All the simulated results are summarized in the following Table 1 and Table 2.

**TABLE I: SIMULATED RESULTS FOR ANTENNA 1 AND 2 w.r.t RETURN LOSS**

<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 = 9.80</td>
<td>-4.55</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>f₂ = 13.39</td>
<td>-7.01</td>
<td>NA</td>
</tr>
<tr>
<td>Slotted</td>
<td>f₁ = 12.6416</td>
<td>-24.9313</td>
<td>0.7945</td>
</tr>
<tr>
<td></td>
<td>f₂ = 16.7591</td>
<td>-12.1438</td>
<td>0.747089</td>
</tr>
</tbody>
</table>

**TABLE II: SIMULATED RESULTS FOR ANTENNA 1 AND 2 w.r.t RADIATION PATTERN**

<table>
<thead>
<tr>
<th>ANTENNA STRUCTURE</th>
<th>RESONANT FREQUENCY (GHz)</th>
<th>3DB BEAMWIDTH (°)</th>
<th>ABSOLUTE GAIN (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>f₁ = 9.80</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>f₂ = 13.39</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Slotted</td>
<td>f₁ = 12.6416</td>
<td>150.525</td>
<td>0.35451</td>
</tr>
<tr>
<td></td>
<td>f₂ = 16.7591</td>
<td>160.752</td>
<td>2.63314</td>
</tr>
</tbody>
</table>

Frequency Ratio for Conventional Antenna

\[ \frac{f₂}{f₁} = 1.366 \]

Frequency Ratio for Slotted Antenna

\[ \frac{f₂}{f₁} = 1.3257 \]

**IV. CONCLUSION**

In the present study, printed microstrip patch antenna design is successfully achieved by introducing a novel feeding method to be able for Ku-band applications. Simulation studies of a hexagonal microstrip printed antenna have been carried out using Method of Moment based software IE3D [20]. Introducing slots at the edge of the patch size reduction of about 11.99% has been achieved. The 3dB beam-width of the radiation patterns are 150.525° (for \( f₁ \)), 160.725° (for \( f₂ \)) 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 (5mm, 2.5mm) considering the centre as the origin.
REFERENCES


[18] Arnab Das, Bipa Datta, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, “A Compact Multi-resonant Microstrip Antenna”, 13th Biennial National Symposium on Antennas and Propagation 2012 (APSYM 2012), Paper ID: 13102, 2012; Co-sponsored by: IEEE Student Branch, Cochin; UGC; Indian National Science Academy; AICTE; Department of Atomic Energy (Govt. Of India); Department of Science & Technology (Govt. Of India); KSCSTE (Govt. Of India); Published by The Directorate of Relations and Publications; ISBN: 978-43-80095-40-0; PP. 99-102, December 2012.


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