H-SHAPE DEFECTED GROUND STRUCTURE (DGS) EMBEDDED SQUARE PATCH ANTENNA

Vidyadhar S Melkeri¹, S L Mallikarjun² P V Hunagund³
¹,²,³Department of PG Studies and Research in Applied Electronics Gulbarga University Kalaburgi

ABSTRACT

In this paper microstrip patch antenna is designed for 2.4GHz frequency. For the antenna miniaturization and bandwidth improvement H-shaped DGS on microstrip patch antenna (MSA) is used. The design of DGS has been analyzed for different dimensions of H-slot and achieved optimized dimensions. The simulation process has been done through Finite Element Machine (FEM) based software High Frequency Structure Simulator (HFSS) software. The properties of antenna such as reflection co-efficient, bandwidth and gain are determined and compared with the properties of single element square patch antenna. Further proposed antennas performance is studied for different size of defect on the same patch antenna. Proposed antenna finds its application in wireless LAN protocols such as Bluetooth, IEEE 802.11 and in 2.4GHz ISM Band.

Keywords: DGS, HFSS, MSA, Bandwidth, Reflection co-efficient.

1. INTRODUCTION

The microstrip patch antenna is one of the most useful antennas for low cost and compact design for RF applications and wireless systems. In wireless mobile communication and satellite applications, microstrip antenna has attracted much interest because of their small size, low cost on mass production, light weight, low profile and easy integration with the other components [1-2]. Although microstrip patch antennas have many very desirable features, they generally suffer from limited bandwidth. So the most important disadvantage of microstrip resonator antenna is their narrow bandwidth. To overcome this problem without disturbing their principal advantage (such as simple printed circuit structure, planar profile, light weight and cheapness), a number of methods and structures have recently been investigated.
An individual microstrip patch antenna has a typical gain of about 6 dB. Several approaches have been used to enhance the bandwidth by perturbing the higher order mode by interpolating surface modification into patch geometry. Gain enhancement by cutting rectangular hole on another inserted layer. A symmetrical hole on the inserted layer is used which is the major frequency in modern wireless communication era [3]. multilayer structures [4], broad folded flat dipoles [5], curved line and spiral antennas [6], impedance matched resonator antennas [7], resonator antennas with capacitive coupled parasitic patch element [8], log periodic structures [9], But the most unique technique to reduce the size of patch is to defect the ground. While comparing the antenna with the defected ground structure and the antenna without the defected ground, the antenna having defected ground structure reduces the size of antenna [10]. The percentage of reduction of size depends upon the ground area that is defected. Defected Ground Structure disturbs the shielded current distribution that depends on the dimension and shape of the defect. The current flow and the input impedance of antenna are then influenced by the disturbance at shielded current distribution due to the DGS structure. The DGS structure can also be used to control the excitation and the electromagnetic waves propagating through the substrate layer [11]. A defect in the ground plane causes to increase in effective capacitance and inductance. In this paper, microstrip antenna for low frequency at 2.4 GHz is designed and simulated using the HFSS software.

## 2. ANTENNA DESIGN PARAMETERS

For the designing of square microstrip patch antenna, the following equations are used to calculate the dimensions of the square microstrip patch antenna [11].

Design consideration for required frequency.

- Length $L$, usually $0.333\lambda_0 < L < 0.5\lambda_0$
- $t << \lambda_0$ patch thickness
- Height of substrate $h$, usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$
- The dielectric constant is considered $2.2 \leq \varepsilon_r \leq 12$

An effective dielectric constant $\varepsilon_{\text{eff}}$ must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\varepsilon_{\text{eff}}$ is little less than $\varepsilon_r$ because the fringing fields around the edge of the patch are not confined in the dielectric substrate but are also spread in the air. The expression for $\varepsilon_{\text{eff}}$ can be given as:

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + 12\frac{h}{W} \right]^{\frac{1}{2}}$$

The dimensions of the patch along its length have now been extended on each end by a distance $\Delta L$, which is given empirically as:

$$\Delta L = 0.412h \frac{(\varepsilon_{\text{eff}} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{\text{eff}} - 0.258)(\frac{W}{h} + 0.8)}$$

The effective length of the patch $L_{\text{eff}}$ now becomes:

$$L_{\text{eff}} = L + 2\Delta L$$

For a given resonance frequency $f_0$, the effective length is given by as:

$$L_{\text{eff}} = \frac{C}{2f_0}\sqrt{\varepsilon_{\text{eff}}}$$
For a rectangular microstrip patch antenna, the resonance frequency for any $TM_{mn}$ mode is given by:

$$f_0 = \frac{c}{2\sqrt{\varepsilon_{\text{eff}}}} \left[ \left( \frac{mL}{L} \right)^2 + \left( \frac{nW}{W} \right)^2 \right]^{\frac{1}{2}}$$

Where $m$ and $n$ are modes along $L$ and $W$ respectively.

For efficient radiation, the width $W$ is given as:

$$W = \frac{c}{2f_0 \sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Substrate dimensions given as:

$$L_g = 6h + L \quad W_g = 6h + W$$

Where,
- $h$ = substrate thickness
- $L$ = length of patch
- $L_{\text{eff}}$ = effective length
- $W$ = width of patch
- $c$ = speed of light
- $f_0$ = resonant frequency
- $\varepsilon_r$ = relative permittivity
- $\varepsilon_{\text{eff}}$ = effective permittivity
- $L_g$ = Length of ground plane
- $W_g$ = Width of ground plane

Based on the above formulae, a conventional square patch antenna has been designed with thickness of substrate as $h=0.16\,\text{cm}$ and relative permittivity $\varepsilon_r = 4.2$. From the analysis the length and width of patch are $3.01\,\text{cm}$ and $3.01\,\text{cm}$ respectively and length and width of substrate are $7.2\,\text{cm}$ and $4.2\,\text{cm}$ respectively. The proposed antenna is fed by using microstrip line feed method. Figure 1 shows the top view of conventional square MSA.
The H-shaped DGS [12] has been embedded in the ground plane of the proposed antenna which consists of the two rectangular slots and one rectangular connecting slot in the ground plane as shown in Figure 2. Figure 3 it shows the bottom view of proposed antenna with DGS.

![Shape of the defect in ground plain](image1)

![Bottom view of proposed DGS antenna](image2)

3. RESULTS AND DISCUSSION

The S11 parameters for the proposed antennas are calculated and simulated reflection coefficients results are presented and compared with each other and are shown in Figure 4.

![Reflection co-efficient verses frequency graph](image3)
From the above figure it is observed that antenna-1 is resonating at 1.61 GHz with impedance bandwidth of 500 MHz when compared to conventional antenna, antenna-1 is showing improved impedance bandwidth of 200 MHz. Further all compared results are tabulated in Table-1. Since the proposed antenna with DGS are resonating below the designed frequency. The size reduction value when compared with conventional antenna in terms of percentage is also tabulated.

<table>
<thead>
<tr>
<th>ANTENNAS</th>
<th>Dimensions of DGS</th>
<th>Resonating Frequency in GHz</th>
<th>Reflection coefficient</th>
<th>BW %</th>
<th>BW in MHz</th>
<th>Size Reduction in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>-</td>
<td>2.36</td>
<td>-16.50dB</td>
<td>1.27</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>Antenna-1</td>
<td>0.4 1.2</td>
<td>1.61</td>
<td>-26.6dB</td>
<td>3.12</td>
<td>500</td>
<td>49.06</td>
</tr>
<tr>
<td>Antenna-2</td>
<td>0.3 1.4</td>
<td>1.59</td>
<td>-24.25dB</td>
<td>3.11</td>
<td>510</td>
<td>50.94</td>
</tr>
<tr>
<td>Antenna-3</td>
<td>0.2 1.6</td>
<td>1.48</td>
<td>-23.20dB</td>
<td>3.36</td>
<td>500</td>
<td>62.16</td>
</tr>
<tr>
<td>Antenna-4</td>
<td>0.1 1.8</td>
<td>1.45</td>
<td>-16.93dB</td>
<td>2.73</td>
<td>400</td>
<td>65.51</td>
</tr>
</tbody>
</table>

The radiation patterns of the proposed antennas are shown in Figure-5 to Figure-9. From the figures it is observed that for conventional antenna the radiation pattern is broadsided which is as shown in Figure 5 and for other antennas with DGS radiation pattern is observed to be nearly Omni directional in azimuth plain as shown in Figure-5 to Figure-9.
Figure 9: Radiation pattern of Antenna-4

Gain is a very important parameter of every antenna. Basically, the gain is the ratio of the radiated field intensity by test antenna to the radiated field intensity by the reference antenna [9]. In this study, the gain of antenna is improved with DGS which is found to be 8.25dB when compared with conventional square MSA (4.62dB).

The smith chart of antenna is shown in figure 10 and it is observed that impedance matching is good.

Figure 10: Smith chart of antenna – 4

4. CONCLUSION

From the detailed study it is observed that the conventional antenna is designed for 2.4GHz and further an H-shaped DGS is incorporated exactly below the patch and by doing this it is observed that antenna is resonating at the lower frequencies. By varying the dimensions of ‘a’ and ‘b’ of DGS it is further obtained that resonating frequency is shifting to lower frequency and from the comparative study the obtained maximum size reduction is 65.51%. By embedding DGS bandwidth, radiation pattern and gain are also improved. These antennas find applications in wireless LAN protocols such as Bluetooth, IEEE 802.11 and in 2.4GHz ISM Band.
REFERENCES