**ABSTRACT**

Micro strip antennas are widely used in many applications due to their low Profile, low cost and ease of fabrication. In some applications it is desired to have a dual band or multiband characteristics. This paper presents the design and simulation of E-shape micro strip patch antenna with wideband operating frequency for wireless application. The shape will provide the broad bandwidth which is required in various application like remote sensing, biomedical application, mobile radio, satellite communication etc. The antenna design is an improvement from previous research and it is simulated using HFSS (High Frequency Structure Simulator) version 13.0 software.

GPS provides specially coded satellite signals that can be processed with a GPS receiver enabling the receiver to compute position, velocity and time. Coaxial feed or probe feed technique is used. Parametric study was included to determine affect of design towards the antenna performance. Radiation performance of the designed antenna is simulated using the HFSS software version 13.0.

**Keywords** - E-shaped slot microstrip, Rectangular Patch, Co-axial probe, GPS, HFSS Software

**I. INTRODUCTION**

A simple GPS repeater consists of an outdoor antenna, narrow band pass filter and low noise amplifier and a reradiating indoor antenna. Figure 1 shows the block diagram of a simple GPS repeater. The outdoor antenna picks the GPS signal from the satellite. This antenna should be wide beam and circular polarized to acquire more satellites. Micro strip circular polarized patch antenna and helical antenna are two suitable choices for this application. The GPS signal received by the outdoor antenna is fed to the input of a narrow band ceramic band pass filter. The filtered signal is then provided to a multi stage low noise amplifier. The amplifier provides the necessary gain so that the signal can be retransmitted inside the building. With the help of indoor reradiating antenna the GPS signal is transmitted inside the buildings. As GPS receiver can be placed anywhere inside the building, a wide beam and circular polarized antenna is required. Micro strip patch antenna is a suitable choice.

**II. METHODOLOGY**

**A. Design of E-Shaped Slot**

**General Design of Patch Antennas**

In this section there is presented a design with the use of Microwave HFSS simulation software.

First of all we have to choose a dielectric constant and substrate height to design an antenna as these are the basics for the design an antenna. They were chosen according to the design frequency (8.83GHz). There was chosen substrate material is air with dielectric constant.

1. Substrate Height =3.2 mm
2. Dielectric Constant=1.0006

**B. Designing parameters:**

* Calculation of the Width (W)
C. Designing Equations

The below equations are used to find out the length and width of patch. The width of the patch is found by

\[
W = \frac{1}{2f \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{\nu_0}{2f} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}
\]

Where the \( \nu_0 \) is the free-space velocity of light

The effective dielectric constant can then be found by

\[
\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + \frac{\lambda}{2W} \right]^{-0.5} \tag{2}
\]

Where the dimensions of the patch along its length have been extended on each end by a distance \( \Delta L \), which is a function of the effective dielectric constant \( \varepsilon_{reff} \) and the width to-height ratio (W/h), and the normalized extension of the length, is

\[
\Delta L = 0.412 h (\varepsilon_{reff} + 0.3) \left( \frac{W}{W + 0.264} \right) \left( \varepsilon_{reff} - 0.256 \right) \left( \frac{W}{W + 0.8} \right) \tag{3}
\]

The actual length of patch (\( L \)) can be determined as

\[
L = \frac{1}{2f \sqrt{\varepsilon_{reff} \mu_0 \varepsilon_0}} - 2\Delta L \tag{4}
\]

D. Antenna Configuration

The configuration of the proposed antenna is shown in Figure 2. The substrate used for this design is air with relative permittivity of 1.0006 and thickness of 3.2 mm. Dimensions of the ground plane are also 60mm X 60 mm.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Label</th>
<th>Dimention (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Patch</td>
<td>Length</td>
<td>( L_a )</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>( W_a )</td>
</tr>
<tr>
<td>Outer Patch</td>
<td>Length</td>
<td>( L_a )</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>( W_b )</td>
</tr>
<tr>
<td>Slot</td>
<td>Main slot width</td>
<td>( W_{sb} )</td>
</tr>
<tr>
<td></td>
<td>Slot width</td>
<td>( W_{sa}, W_{sb} )</td>
</tr>
<tr>
<td></td>
<td>Slot A length</td>
<td>( L_sA )</td>
</tr>
<tr>
<td></td>
<td>Slot B length</td>
<td>( L_sB )</td>
</tr>
<tr>
<td>Centre Arm</td>
<td>Width</td>
<td>( W_c )</td>
</tr>
<tr>
<td>Feed Point</td>
<td>Width</td>
<td>( W_{c/2} )</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>( L_f )</td>
</tr>
<tr>
<td>Substrate</td>
<td>Thickness</td>
<td>( H )</td>
</tr>
</tbody>
</table>

Table 1: Micro Strip Patch Antenna Specifications

By using the above configuration the proposed antenna is like as the figure 2, the total view of a simple E-slot patch antenna is designed by using HFSS software. In this we use a coaxial feeding with aperture type. The aperture slab is at the height of 3.2 mm from the ground. The main purpose of this is to improve the matching between the feeding and the radiating element.

![Figure 2: Cut plane view of antenna](image-url)

E. Simulation Setup

The antenna’s resonant properties were predicted and optimized using High Structure simulation software Ansoft version 11. The design procedure begins with determining the length, width and the type of dielectric substance for the given operating frequency. Then using the measurements obtained above simulation has been setup for the basic rectangular micro strip antenna and the parameters are optimized for the best impedance matching. Furthermore two parallel slots are incorporated and optimized such that it closely resembles E shape; this increases the gain of the antenna. After that two more parallel slots and one perpendicular slot are incorporated and optimized such that it closely resembles U shape. Then dielectric substrate of dielectric constant of 1.0006 introduces to decrease the size of the antenna and to further enhance the...
bandwidth. At last the probe feeding is introduced for attaining a required bandwidth, resonating frequency and gain value.

F. Geometry of Antenna

The geometry of the designed antenna is shown in the Figure 3. The antenna is made of a single patch on top, one layers of dielectric (air) and a vertical probe connected from ground to the upper patch.

The main E shaped patch has $W_a \times L_a$ dimension while the outer patch has $W_b \times L_b$ dimension. The antenna is fed by a SMA connector positioned at the center arm. The center of probe is positioned at $(W_c/2, L_f)$.

![Figure 3: Design geometry of the E-shape micro strip patch.](image)

Parallel slots in this design are responsible for the excitation of next resonant mode i.e. main parallel slot excite 2nd resonant frequency while outer slot excite 3rd resonant frequency. Slots length ($L_{sA}$ and $L_{sB}$), slot width ($S$), main slot width ($W_{sB}$) and center arm ($W_c$) controls the frequency of the next resonant mode. Figure 2 shows the cut plane view of the antenna. The patch and ground are separated by closed-cell low loss air of thickness 3.2 mm. Dielectric constant for this foam is 1.0006, and it benefits to obtain wider bandwidth and higher gain.

Air gap was used as substrate and infinite ground was assumed. This paper design a finite set of ground dimension which is defined by $W_g \times L_g$. SMA connector design is according to specification in using Teflon of dielectric constant = 2.08.

![Figure 4: Design of E-shape micro strip patch in HFSS software](image)

III. RESULTS AND EXPLANATIONS

A. Return Losses

Figure 5 illustrates both the simulated and experimental results of the antenna return loss. Here, return loss is defined as

$$R = 20 \log_{10} \left| \Delta \right|$$

(5)

where $\Delta$ is the reflection coefficient. As shown in this figure, simulated values of the first and second resonant frequencies are 2.31 GHz and 3.78 GHz, respectively. Current paths of the 1st and 2nd modes are shown. Dash-dot lines show the average length of current paths for each mode. The resonant frequencies can be calculated approximately as follows:

$$f_1 = \frac{c}{2 \sqrt{\varepsilon_{\text{eff}}} L_1}$$

(6)

$$f_1 = \frac{c}{2 \sqrt{\varepsilon_{\text{eff}}} L_2}$$

(7)

Where $L_1$ and $L_2$ are the average lengths for current paths of the 1st and 2nd resonant modes and $c$ is the free space velocity of light. The effective permittivity is also given by

$$\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{105}{h}ight)^{-0.555}$$

(8)

Where $h$ and $W$ are height of the substrate and width of the patch, respectively. The above equation, which is given in, is valid for single layer substrates. However, while the effect of L-shaped feed system is negligible, this equation can be used for two-layered substrates provided that the parameter $h$ is substituted by the total height of $h_1 + h_2$. The average lengths for current paths of the 1st and 2nd resonant modes can be obtained by using the following approximate relations:

$$L_1 = \alpha_1 l_1 + \alpha_2 w_3 + \alpha_3 W$$

(9)

$$L_2 = \beta_1 d_1 + \beta_2 d_2 + \beta_3 l_s + \beta_4 w_s$$

(10)

Based on results of several simulations, optimum values of $\alpha_i$ and $\beta_i$ in the above equations are obtained as follows.
\[ \alpha_1 = 0.385; \alpha_2 = 0.445; \alpha_3 = 1.000 \]
\[ \beta_1 = 1.097; \beta_2 = 0.630; \beta_3 = 0.876; \beta_4 = 1.412 \]

The return losses are shown in the below figure.

B. Radiation Pattern

The radiation field of the micro strip antenna may be determined using either an electric current model or a magnetic current model. In the electric current model, the current is used directly to find the far-field radiation pattern. The electric current for the (1,0) patch mode. If the substrate is neglected (replaced by air) for the calculation of the radiation pattern, the pattern may be found directly from image theory. If the substrate is accounted for, and is assumed infinite, the reciprocity method may be used to determine the far-field pattern. In the magnetic current model, the equivalence principle is used to replace the patch by a magnetic surface current that flows on the perimeter of the patch.

The radiation Pattern of antenna is shown in below figures 6,7

C. 3-D View of Radiation Pattern

The radiation pattern is main concentration for the wide band application. For wide band application the effect of the radiation up to 30 miles. The gain must be high for this type of application the radiation pattern for E-shape is

The Figure 6 and 7 show the radiation pattern for the antenna at 8.73GHz. HPBW is the angular separation which the magnitude of the radiation pattern from the peak of the main beam decreases by 50% or -3 dB. HPBW (angle) is 70° for Optimum Frequency of 8.73 GHz.

D. Field Distribution

The E-field distribution and H-Field distribution for E-shape design is
For the view of field distribution there is no uniform distribution in the single u-slot patch antenna. For non-uniform distribution of these fields the return losses are somewhat high. For decrease the return losses there must perfect matching between coaxial system and the radiating element then we can easily remove the return losses.

E. VSWR

![VSWR for E-shape patch antenna](image)

Figure 11: VSWR for E-shape patch antenna

F. GAIN

Another useful measure describing the performance of an antenna is the gain. Although the gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Remember that directivity is a measure that describes only the directional properties of the antenna, and it is therefore controlled only by the pattern. Gain of an antenna (in a given direction) is defined as “the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π.” In equation form this can be expressed as

\[
\text{Gain} = 4\pi \frac{\text{radiation intensity}}{\text{total input power}} = 4\pi \frac{U(\theta, \phi)}{P_{\text{in}}} \tag{11}
\]

The result of gain is shown in below figure

![Gain](image)

Figure 12. Gain

![Gain](image)

Figure 13: Gain

| Different Antenna Parameters at Different Frequencies |
|-------------------------------|-----------------|-----------------|-----------------|
| Frequency(GHz) | 8.73 | 11.45 | 13.15 |
| Gain (dB) | 4.33 | 5.43 | 4.79 |
| Radiation Efficiency(dB) | 5.142 | 7.254 | 9.6069 |
| Front to back Ratio (dB) | 30.3170 | 23.8817 | 13.0879 |
| Max U(W/Sr) | 0.000010 | 0.000008 | 0.000001 |
| Peak Directivity | 8.8615 | 7.6318 | 1.17309 |
| Radiated Power(W) | 0.000014 | 0.000014 | 0.000010 |
| Accepted Power(W) | 0.000046 | 0.000073 | 0.000092 |
| Incident Power(W) | 0.000033 | 0.000060 | 0.000083 |

Table 2: Values for radiation parameters for each frequency

H. Different Antenna Parameters at Different Thickness of Substrate
Table 3: Values for radiation parameters for different thickness

I. Different Antenna Parameters at Different Main Arm Widths

Table 4: Values for radiation parameters for different main arm widths

J. Different antenna Parameters at Changing Air Gap with C-Foam

Table 5: Values for radiation parameters for different substrate materials

IV. CONCLUSION

In this paper, an E-shaped wideband microstrip patch antenna using Air substrate has been designed, simulated, optimized and analyzed using HFSS (High Frequency Structure Simulator) software version 13.0. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern. The design was optimized to meet the best possible result. Substrate used was air which has a dielectric constant of 1.0006. The results show the wideband antenna is able to operate from 8.80 GHz to 13.49 GHz frequency band with optimum frequency at 8.73 GHz. Due to the compact area occupied. The proposed antenna is promising to be embedded within the different portable devices employing GPS applications.

REFERENCES


