DESIGN AND ANALYSIS OF BROADBAND CIRCULAR MICROSTRIP PATCH ANTENNA USING STUB LOADED STACKING (SLS) TECHNIQUE

Aditya Kumar Gupta\textsuperscript{1}, Amit Dwivedi\textsuperscript{2}, Dushyant Singh\textsuperscript{3}
\textsuperscript{1,2}B.Tech Scholar, \textsuperscript{3}Asst. Professor
Dept. of Electronics & Comm. Engg., RBSET Campus, Agra (India)

ABSTRACT

Circular microstrip antennas have several interesting properties that make it attractive in wireless applications. A circular microstrip antenna is designed in order to obtain the required parameter responses at 4 GHz by using IE3D software based on the method of cavity model due to simplicity and ease of analysis. A circular ring microstrip antenna is designed for TM mode at the resonance frequency of 4 GHz, and analyzed for different parameters such as return loss, VSWR, input impedance and bandwidth. Analysis shows that the size of designed antenna is small at the cost of low bandwidth. The circular microstrip antenna is fed by a coaxial probe (Teflon probe) and glass epoxy is used with the specified information include the dielectric constant of substrate (\( \varepsilon_{r} = 4.2 \)), the resonant frequency (\( f_r = 4 \) GHz) and substrate height (\( h=1.6 \)mm). The circular microstrip antenna exhibits appropriate required parameters depend on the feed point position, size of the circular patch. A prototype of a circular microstrip antenna has been built and tested by spectrum analyzer. There is slight difference between the measured and simulated results caused by several factors that would be discussed in result part.

Keywords: Circular Microstrip Antenna, Coaxial Probe, Efficiency, Gain, Bandwidth, Stack & Stub.

I. INTRODUCTION

A microstrip antenna in its simplest form consists of a radiating patch (of different shapes) on one side of a dielectric substrate and a ground plane on the other side. Microstrip antennas are used in communication systems due to simplicity in structure, conformability, low manufacturing cost, and very versatile in terms of resonant frequency, polarization, pattern and impedance at the particular patch shape and model [1]. The performance of the antenna is affected by the patch geometry, substrate properties and feed techniques [8]. In a circular microstrip antenna, the mode is supported by the circle shape on a substrate with height is very small compared to wavelength. Referring to
the dimensions of the circular patch, only one degree freedom to control the radius, of the patch. This would not change the order of the modes but the absolute value of the resonant frequency [1].

In this paper, the circular microstrip antenna is being fed by a coaxial probe. We have made our antenna of pyramidal shape using stack technique as well as stub technique. The pyramid shape of antenna is accomplished by the circle and the rings. The rings are above the circle and hence making the pyramid structure. The main advantage of stack technique is to enhance the bandwidth.

II. METHODS OF ANALYSIS

- The Transmission line model
- The Cavity model
- The MNM

In Transmission line model the microstrip radiator element is viewed as a transmission line resonator with no transverse field variations. In the cavity model, the region between the patch and the ground plane is treated as a cavity that is surrounded by magnetic walls around the periphery and by electric walls from the top and bottom sides. The MNM for analyzing the MSA is an extension of the cavity model. In this method, the electromagnetic fields underneath the patch and outside the patch are modelled separately [9].

III. CIRCULAR MICROSTRIP PATCH ANTENNA

Other than the rectangular patch, the next most popular configuration is the circular patch or disk, as shown fig. 1 it also has received a lot of attention not only as a single element but also in arrays. The modes supported by the circular patch antenna can be found by treating the patch, ground plane and the material between the two as a circular cavity. As with the rectangular patch, the modes that are supported primarily by a circular microstrip antenna whose substrate height is small (h<<\lambda_0) are TM_2 where z is taken perpendicular to the patch. As far as the dimensions of the patch, there are two degrees of freedom to control (length & width) for the rectangular microstrip antenna. 

![Circular Microstrip Patch Antenna](https://www.ijarse.com)

**Fig.1 Reference Circular Microstrip Patch Antenna**
Therefore the order of the modes can be changed by changing the relative dimensions of the width and length of the patch (width to length ratio). However, for the circular patch there is only one degree of freedom to control (radius of the patch). Doing this does not change the order of modes, however, it does change the absolute value of the resonant frequency of each.

III.1 EQUATIONS USED FOR ANALYSIS

a) Equations used

Basically a circular microstrip antenna can only be analyzed via the cavity model and full-wave analysis. The cavity model also provides the method that the normalized fields within the dielectric substrate can be found more accurately and it does not radiate any power. According to the cavity model approach the radius of the antenna is [1]:

\[ F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \]

\[ a = \left\{ 1 + \frac{2h}{nF} \ln(nF) + 1.776 \right\} ^{\frac{1}{2}} \]

\[ \varepsilon_r = \text{Dielectric constant of the substrate } = 4.2 \]

\[ f_r = \text{the resonant frequency (in Hz) } = 4\text{GHz} \]

\[ h = \text{height of the substrate (cm) } = 0.159 \]

It is found that an inset feed circular patch antenna having patch radius of 10.24mm resonant at frequency 4 GHz, when it is designed on glass epoxy FR-4 substrate (\( \varepsilon_r = 4.2 \tan \delta = 0.02 \) h= 0.159cm) with infinite ground plane. The simulated reflection coefficient (\( S_{11} \)) variation of same antenna with frequency obtained by using IE3D software has been shown in fig.2. This variation indicates the resonance frequency of antenna. The impedance bandwidth corresponding to resonance frequency are very low. The gain and efficiency of antenna are also very poor. These outcomes suggest that circular patch antenna in its present form is not suitable for application satellite communication system. Therefore, this patch geometry has been modified by introducing stub loaded stack (SLS) technique.

Fig.2 S parameter of reference circular microstrip patch antenna
IV. CIRCULAR PATCH ANTENNA WITH STUB LOADED STACK TECHNIQUE (SLS)

The single layered circular patch geometry modified by using SLS technique as shown in fig. The circular patch with infinite ground plane designed on glass epoxy FR-4 substrate still has radius of 10.24mm. We have made our antenna of pyramidal shape using stack technique as well as stub technique. The pyramid shape of antenna is accomplished by the circle and the rings. The rings are above the circle and hence making the pyramid structure. There are three layer of rings present above the reference circular microstrip antenna. We have used stub technique in our project for dual band operation.

4.1 Design

Ground patch dimension

Radius (a) = 10.24mm

Stack Patches:

1. Ring – Inner diameter = 8mm Outer diameter = 9mm
2. Ring – Inner diameter = 6mm Outer diameter = 8mm
3. Ring – Inner diameter = 3mm Outer diameter = 6mm

Stub:

Length = 4mm.

Width = 1mm.

Degree of rotation = 5°

The flow of work then continues with the fabrication process. This process begins with the layout. After that, the etching process was carried out according to the dimensions from the simulation. Finally, the antenna was measured using a spectrum Analyzer to compare the simulation and the measurement results. Figure 1 shows the proposed circular antenna with the circular patch and the probe feed.

This circular patch is printed on glass epoxy substrate having dielectric constant of 4.2 and thickness, h=1.6mm. The objective of the patch is to resonate at 4 GHz.
V. RESULTS AND DISCUSSION

From the results of simulation of hardware it is found that the value of return loss is \(-25.40\) dB & the bandwidth is 338 MHz at the resonant frequency of 4 GHz as shown in figure and the coordinates of feed point being \((x=2,y=5)\).

In this design the performance of the antenna depends on the height of antenna. The BW of the MSA increases with an increase in substrate thickness and decrease in the dielectric constant.

After using SLS technique we found that bandwidth of MSA is increased which is our objective. The simulation results of MSA after fabrication using SLS technique are following.

![Fig.4 Return loss after using SLS technique](image)

![Fig.5 VSWR after using SLS technique](image)

V.1 Comparison between simulated and Measured Results at the resonant frequency

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Reference</th>
<th>After using SLS Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius((a))</td>
<td>10.24mm</td>
<td>10.24mm</td>
</tr>
<tr>
<td>Operating frequency</td>
<td>4GHz</td>
<td>4GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>137MHz</td>
<td>338MHz</td>
</tr>
<tr>
<td>Return loss</td>
<td>-22.03dB</td>
<td>-25.40Db</td>
</tr>
</tbody>
</table>
There are several factors responsible for the difference between the simulated & practically obtained values. During fabrication, the improper handling can influence the obtained result such as during etching process; the circular patch might not be precisely obtained, since at higher frequency the MSA are very sensitive to dimensions of the patch.

The difference in the result could be due to parasitic components in the screw that are used to fix the antenna. Here the screws act as capacitor that exhibit fringing effect between the patch and ground plane. Due to this effect the amount of signal transmitted to air reduces so there must be sufficient distance, larger than $\lambda/4$, between the patch & screws to avoid this problem. The skin effect due to solder leads used to connect the probe to the patch is another reason for the mismatch in the simulated and practical result.

Another reason is the loss due to the substrate properties. A higher dielectric loss will result in worst return loss and VSWR. So a good substrate with low value of loss must be chosen to prevent some loss in the antenna [5].

VI. CONCLUSION

Design of circular ring microstrip antennas has been investigated via the cavity model. A circular microstrip antenna with a probe feed is obtained and the required parameters at the frequency of 4 GHz have been investigated successfully. From the simulated results it is found that the return loss is -22.0 dB and bandwidth is 137 MHz and from the measured values it is found that the return loss is -25.40 dB and bandwidth is 338 MHz at the resonant frequency of 4 GHz. The microstrip antenna performance can be upgraded concerning the feed type, the size of the patch and the substrate used.

REFERENCES