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# Circle Embedded Rectangular Microstrip Patch Antenna for High Gain Application

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## ABSTRACT

In this paper a rectangular microstrip patch antenna with a rectangular slot at the left side and a circle embedding in a square slot is proposed. The antenna is resonant at 9 GHz frequency. The antenna is good for directional applications. The antenna can be used for GPS application and for microwave virus sanitizer. The gain of the antenna is 9.059 dBi. The directivity of the antenna is 10.56 dBi. The return loss of the antenna is -16.6 dB. The antenna is designed for X band application. The dielectric substrate used is RT Duroid with dielectric constant 2.2 and loss tangent 0.0004.

## Keywords

Microstrip patch antenna, square slot, gain, directivity, return loss, X band

## 1. INTRODUCTION

Microstrip patch antenna consists of a dielectric substrate which has a radiating patch on one side of the dielectric which has a ground plane on the other side. Microstrip patch antenna radiates because of the fringing fields along the edges of the patch. Microstrip patch antennas have several well-known advantages such as light weight, low volume, low profile planar configurations and ease of fabrication and can be easily integrated with high speed MICs. However, the MPA has low gain and narrow bandwidth at higher frequencies. To overcome its inherent limitation of low gain, many techniques have been suggested. Conventional way to get high gain is to form an array with appropriate feeding network. However, intricate feeding mechanisms to meet the suitable phase delays make the antenna system complicated and also cause signal loss. Here, a simple type of microstrip patch antenna is proposed with two slots and a circle is embedded in the structure. The structure is showing good results in terms of gain and directivity. Its return losses are also of acceptable level.

## 2. ANTENNA DESIGN

In this paper, a square slot is cut in the rectangular patch of side 10mm and a circle is embedded in the slot with the radius of 4mm. A slot is also cut at left side of the patch with width and depth of 8mm and 6mm respectively. Coaxial feed is used to excite the antenna. Probe feed is given at x=13 and y=5 with the origin at (0, 0). The geometry of the proposed antenna is shown in the figure. The antenna is simulated at 10 GHz frequency with electromagnetic simulation tool IE3D from Zeland software. It is based on method of moments simulation. The dielectric substrate used is Rogers RT Duroid with dielectric constant 2.2 and loss tangent 0.0004. The patch is made up of copper. The entire structure is on single layer. The details of the structure is given below-

Length of the rectangular patch= 30mm

Width of the rectangular patch = 15mm

Side of the square slot =10mm

Width of the rectangular slot = 8mm

Depth of the rectangular slot = 6mm

Radius of the circle = 4mm

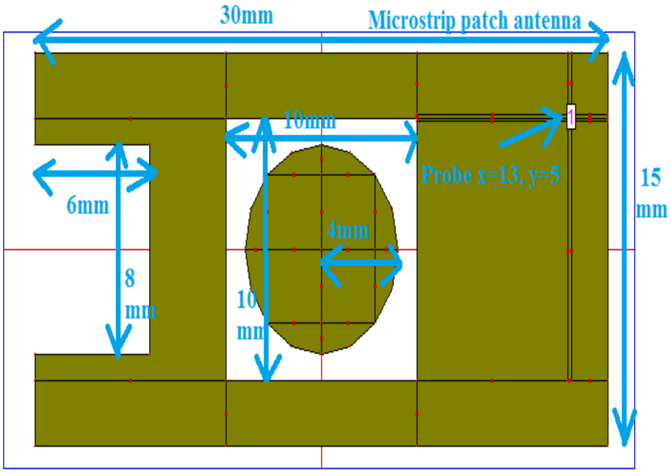


**Fig.1 Geometry of the proposed antenna**

## 3. SIMULATION RESULTS

## Return Loss vs. Frequency Graph

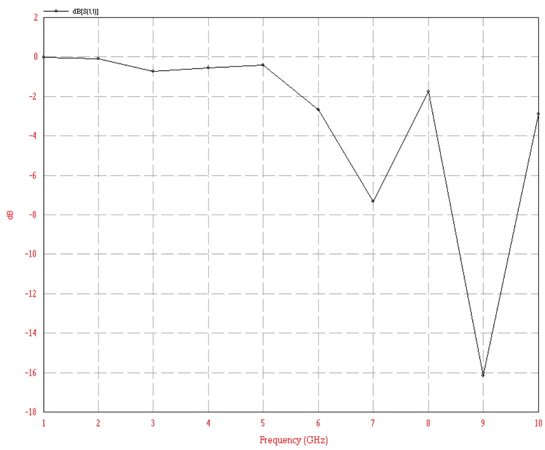


**Fig.2 Return loss vs. frequency graph**

The antenna is giving return loss of -16.16 dB at 9GHz frequency. The reflection coefficient calculated is 0.00. Voltage Standing Wave Ratio is 1.1.

## Directivity vs. Frequency Graph

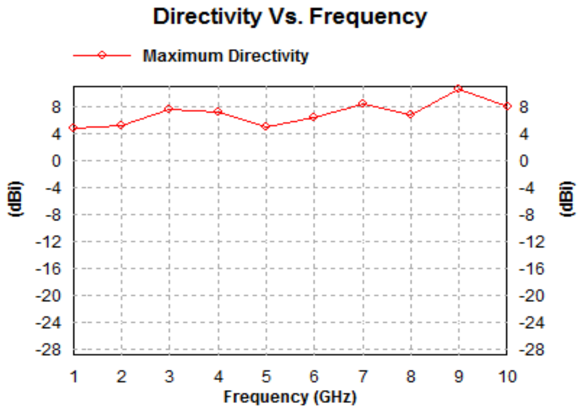


**Fig.3 Directivity vs. frequency graph**

The directivity of the proposed antenna is 10.56 dBi which is pretty good.

## Gain vs. Frequency Graph

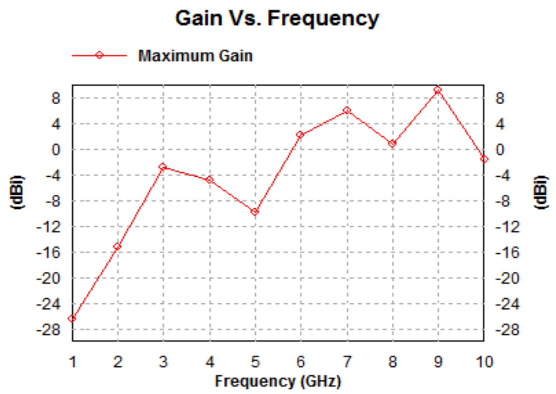


**Fig.4 Gain vs. frequency graph**

The gain of the proposed antenna is 9.059 dBi which is high as compared to conventional antenna. The conventional antenna has a gain of 3 to 5 dB. But this antenna gives a high gain which is close to 9 dB.

## Efficiency vs. Frequency Graph

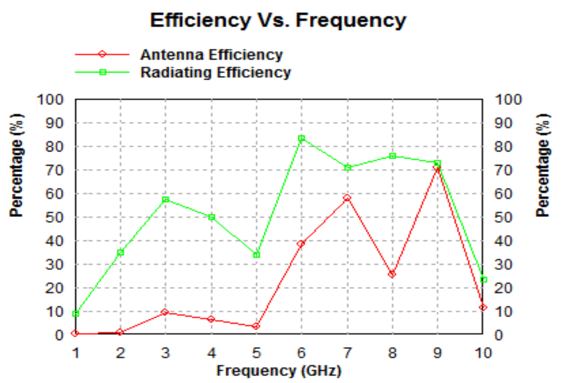


**Fig.5 Efficiency vs. frequency graph**

The antenna efficiency of the proposed antenna is 70.74%. Radiating efficiency is 72.50%.

## Elevation Pattern Gain

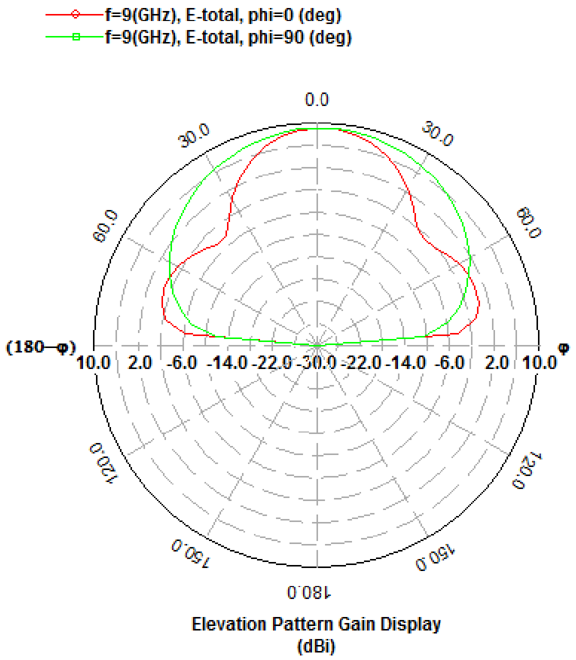


**Fig.6 Elevation pattern gain graph**

## Azimuth Pattern Gain

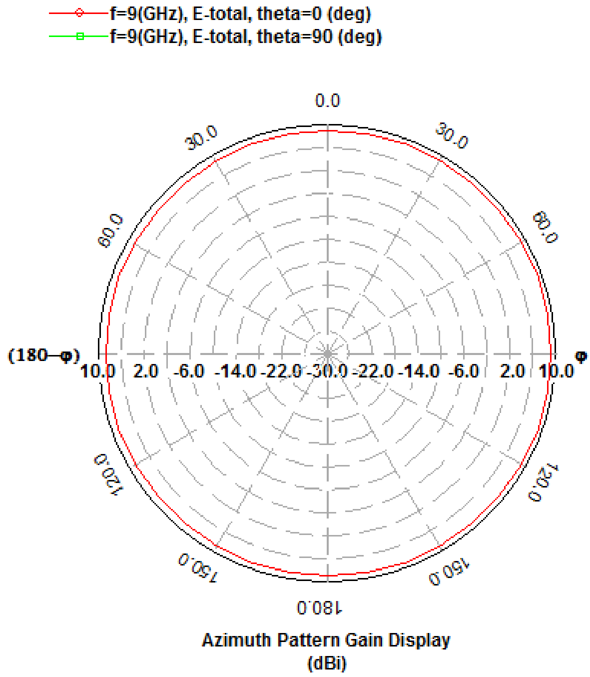


**Fig.7 Azimuth Pattern Gain graph**

## 3D Radiation Pattern

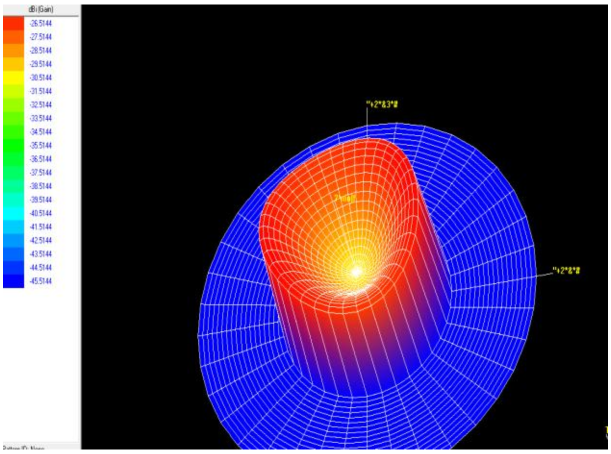

**Fig.8 Three-dimensional radiation pattern**

## 4. RESULTS AND DISCUSSION

The proposed antenna is resonant at 9 GHz frequency. The antenna is good in terms of efficiency. The antenna efficiency is given as –

$$\text{Antenna Efficiency} = \frac{\text{radiated power}}{\text{incident power}} \times 100$$

$$= \frac{0.00707466W}{0.01W} \times 100 = 70.7466\%$$

$$\text{Radiation Efficiency} = \frac{\text{radiated power}}{\text{input power}} \times 100$$

$$= \frac{0.00707466W}{0.00975788W} \times 100 = 72.5021\%$$

Gain may be defined as how effectively the antenna concentrates its energy in the desired direction without increasing the power. Gain is closely related to the directivity of the antenna.

$$Gain = \eta \times directivity$$

Where, $\eta = efficiency$

Gain of the antenna is 9.059 dBi.

$$vswr = \frac{1+\Gamma}{1-\Gamma} = \frac{1+0.1557}{1-0.1557} = 1.369$$

Where, $\Gamma$ = reflection coefficient = 0.1557

Return loss is the difference in dB between forward and reflected power. Return loss is given as-

$$RL = 20\log_{10}\Gamma dB$$

$$= 20\log_{10} 0.1557 dB = -16.16 dB$$

Thus, Return loss of the proposed antenna is -16.16 dB. Antenna gives good performance when a slot is cut as compared to the antenna without slot. Also, when circle is embedded in the square slot the performance of the antenna is appreciably increased. The antenna is highly directional as its directivity is more than 10 dB. The detailed description of antenna performance is given below-

| | |
|---|---|
| Frequency: | 9 (GHz) |
| Incident Power: | 0.01 (W) |
| Input Power: | 0.00975788 (W) |
| Radiated Power: | 0.00707466 (W) |
| Average Radiated Power: | 0.000562984 (W/s) |
| Radiation Efficiency: | 72.5021% |
| Antenna Efficiency: | 70.7466% |
| Linear Properties: | |
| Linear Gain: | 9.05977 dBi |
| Linear Directivity: | 10.5627 dBi |
| Linear Maximum: | at (0, 0) deg. |
| 3dB Beam Width: | (39.0597, 76.6737) deg. |
| RH Circular Properties: | |
| Circular Gain: | 7.37597 dBi |
| Circular Directivity: | 8.87892 dBi |
| Circular Maximum: | at (10, 100) deg. |
| 3dB Beam Width: | (39.7153, 69.7859) deg. |
| No. 1 Port: | Inc=1/0 (V), Zs=(50,0) Ohms, Zc=(50,0) Ohm |
| : | V=1.02106/-8.75031 (V), I=0.0200586/8.90971 (A) |
| : | Inc=1/-1.66979e-014 (V), Ref=0.155602/-86.6212 (V) |
| Frequency: | 10 (GHz) |
| Incident Power: | 0.01 (W) |
| Input Power: | 0.00488976 (W) |
| Radiated Power: | 0.00113273 (W) |
| Average Radiated Power: | 9.01398e-005 (W/s) |
| Radiation Efficiency: | 23.1654% |
| Antenna Efficiency: | 11.3273% |

## 5. CONCLUSION

Rectangular microstrip patch antenna with a circle embedded in the square slot of the rectangular microstrip patch antenna and a rectangular slot at the left side of the structure has been analyzed. The antenna is found to be good for high gain application. The antenna is showing linear polarization. The antenna is resonant at 9 GHz frequency. The return loss obtained is -16.16 dBi and the antenna is giving a gain of 9.059 dBi. The directivity is 10.56 dBi. Embedding a circle in the square slot is an advantageous approach to obtain better impedance matching at the desired resonant frequency. The better return losses are due to the slots cut in the rectangular patch while the better gain is due to the circle embedded in the patch. This antenna is very easy to fabricate and implement in any circuit and also of low cost as this structure is not complicated.

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