Slotted Rectangular Microstrip Patch Antenna for Radio Detection and Ranging(RADAR)

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***Abstract* — The rectangular microstrip patch antenna is presented with rings and two circular slots. This antenna is designed and simulated in the CST studio suite, for radar systems. The parameters of the antenna are analyzed, it obtains the gain of 5.67 dB at 9.4GHz frequency. The radiation efficiency is 92% and total efficiency of 87%. The designed patch antenna works in the frequency range of 9.177-9.557 GHz, maximum gain at 9.4 GHz. It is observed, the antenna is working at frequency 9.4 GHz for radio detection and ranging(RADAR) applications.**

Keywords – radar, microstrip antenna, semi-circular rings, patch antenna, gain.

I. INTRODUCTION

In the modern era, radar is one of the technologies that is emerging in today's world with a very high rate, radar is a device that radiates the waves and receives it depending on its parameters of working. It consists of a transmitter that emits radio waves and an antenna that transmits it to the space. And the information contained by the transmitted signal can be received by another antenna[1]. Radar systems are advanced in recent times, as we connect with the world around us through the wireless transmission and reception of waves. Radars are used in many different applications such as, monitoring weather conditions, advanced signal processing, navigation, targeting and surveillance. The antenna used in the radar should be efficient and with high gain and directivity to use it in the described applications.

For the transmission and the reception of the signal, the antenna is used. The antenna transmits and receives the electromagnetic waves, typically of radio frequencies. Basically, it is designed to convert electrical signals into waves and electromagnetic waves to the electrical signal depending on the application of the particular antenna. The design of an antenna based on its use, it can be designed in any shape or size according to the requirement. Antennas can be used for many applications such as, mobile communication, GPS navigation, wireless networking, broadcasting of data and radar systems etc. The designed antenna is particularly focused on the application of radar systems.

The principle of radar systems is based on the reflection of signal when collide with an object. The object returns a small part of energy which can be received with the help of an antenna. For the particular application, any antenna such as, dipole antenna, linear array, non- uniform array antenna, horn antenna microstrip patch antenna and many more. Of which, horn antennas have moderate gain. Here, microstrip patch antenna is used which emits narrow beams in one direction. Table 1 gives the radar bands and their frequency range.

Table 1. Radar Frequency Bands [2]

Radar Band	Frequency (GHz)
Ka	26.5-40
K	18-26.5
Ku	12.5-18
X	8-12.5
C	4-8

In history, various antennas are designed for their use in radar systems but, due to the large size and weight, high cost they are very less in use[3]. Therefore, to reduce the size and weight of the antenna, microstrip patch antenna is designed to detect and locate the objects by transmitting electro-magnetic waves through the antenna[4]. Also, it is easier to integrate with other electronic components. But, the low efficiency, makes it difficult to use it for long distances and also, the output may differ by a small value. Therefore, the design of antenna requires absolute considerations for better results and one more way to improve is to use the proper impedance bandwidth.

The microstrip patch antenna is designed on a dielectric substrate sandwiched between the designed antenna and the ground plane. The ground plane and the structure of the antenna are made of a conducting material. As mentioned above, the microstrip patch antenna can be of any shape. In this paper, a rectangular patch antenna is used as it is easier to make the antenna with desired dimensions. Also, they can operate at multiple frequencies, therefore it is easier to set the dimensions of the antenna to work for the particular frequency. Due to the simplicity in design, low cost it is preferable.

The material used in the microstrip patch, feed and the ground are copper(annealed). As it has low weight and volume that makes the antenna easier to handle. Also, the fabrication cost is less. Impedance matching and radiation is produced as, the feed is connecting the patch.

The designed antenna is rectangular and slotted by two semi-circular rings by taking center of the length side as a center. The simple feed is given to the antenna at the center of the lower edge to introduce the energy in the antenna. The radiation pattern and the impedance of the antenna can be set according to the use of the particular antenna by defining the dimensions and the location of the feed given to the antenna.

II. LITERATURE SURVEY

Many antennas are made to meet the requirements of a radar system, but they are of huge size and weight and therefore hard to maintain and transport. Also, the antennas used, should be of high gain and directivity to meet the requirements of a radar system. In the current research, microstrip antenna grabbed much attention because of their ease of fabrication and compact in size. The series-fed microstrip antenna is proposed in [5], the work reported in this, has difficulties to achieve a good value (i.e., less value) of s11 parameter. In [6], a hybrid band antenna for Ku band is represented, for the frequency range of 14.9 to 15.1 GHz. The designed antenna gives large bandwidth, but the gain of the antenna is very less.

To remove the problems of low efficiency, some authors moved towards the differential microstrip patch antennas. Although it gives wider bandwidth, the major disadvantage of differential microstrip patch antenna is, extra radiation occurs from its feed and junctions, as represented in[7-8].

As the differential microstrip patch antenna is applied, the gain of the antenna reduces. According to the work proposed by Haq Nawaz and Ibrahim Tekin in their paper, the gain of the antenna is very less, where they represented a differential fed patch antenna [9].

III. ANTENNA DESIGN AND GEOMETRICAL DETAILS

The proposed microstrip patch antenna is designed as a rectangular patch of size 18.42 x 14.8 mm. the particular antenna is presented with a substrate FR-4(lossy) substrate, dielectric constant of the substrate is 4.3, the height and the loss tangent are 1.6 mm and 0.025 respectively. The FR-4 substrate is used as it has less loss and is available at low cost, and can be found easily. The proposed antenna has two semi-circular ring slots centered at the side edges of radius 7.4 mm, half of the length of the rectangular patch and width of the ring slots is 1 mm. Also, two circular slots are carved at 6.25 mm from the center of the patch antenna, the radius of the circular slots is 1.5 mm. The semi-circular ring slots and the two circular slots define the nature of polarization. The rectangular patch antenna is proposed at the impedance of 50 Ω, as it is required for impedance matching.

$$w = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$$

And, $$L = \frac{1}{2f_r\sqrt{\epsilon_{eff}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L \qquad [10]$$

Where, v_0 is velocity of light in free space, f_r is the required frequency and μ_0 *and* ϵ_0 are the permeability and permittivity respectively. The above two equations are used to calculate the length and width of the patch for the desired frequency, i.e., 9.4 GHz. The calculated length of the patch is 18.42 mm and width 14.8 mm.

The material used in the microstrip patch, feed and the ground are copper(annealed). As it has low weight and volume that makes the antenna easier to handle. Also, the fabrication cost is less. Impedance matching and radiation is produced as, the feed is connecting the patch. The designed antenna is designed and analyzed using the CST studio suite. The geometric details of the proposed antenna are shown in figure 1.

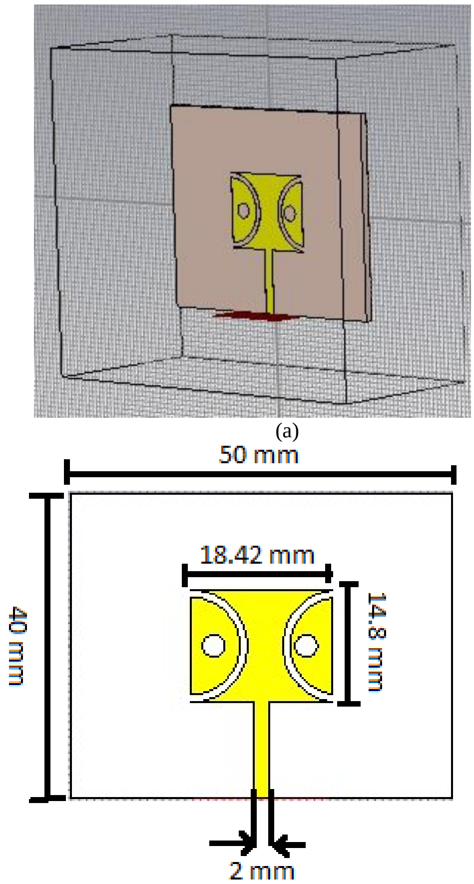

Fig. 1. Rectangular microstrip patch antenna, (a) side view and (b) front view with dimensions.

The proposed antenna is designed at the substrate of height 1.6 mm followed by a ground of height 0.035 mm. the size of the substrate and the ground are taken as 50 x 40 mm. the dimensions of the microstrip patch antenna are described by the calculations in the following table.

Table 2 Dimensions for designed antenna

Name	Dimension (in mm)
Wg	50
Lg	40
t	0.035
h	1.6
Lf	15.5
W_0	2

The proposed rectangular microstrip patch antenna dimensions are 50 x 40 mm of ground and the substrate. The given feed has the dimensions of 2 x 15.5 mm. The height of the substrate is 1.6 mm and that of ground is 0.035mm.

IV. SIMULATION RESULTS

A. *Return Loss*

Figure (2) shows s11 parameter plot with respect to frequency simulated on CST. It is observed in the return loss plot, the s11 in the range of 9.17 GHz to 9.55 GHz is less than -10 dB. Hence, the desired frequency has s11 parameter (return loss) less than -10 dB.

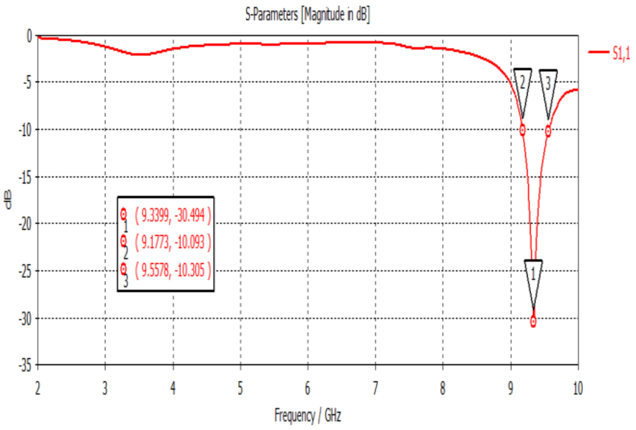

Fig. 2. Reflection coefficient s11 of the patch antenna in CST

B. *VSWR and Impedance bandwidth*

VSWR plot with respect to the frequency(in GHz) is shown in the figure (3), it measures the power, supplied by the designed antenna. The VSWR is defined as the ratio of maximum voltage to minimum voltage. It can be clearly observed that the VSWR at the designed frequency is 1, therefore, there is no power reflection back to the source. From figure (2), the bandwidth of the designed antenna can be seen as 380 MHz (9.557 – 9.177 GHz).

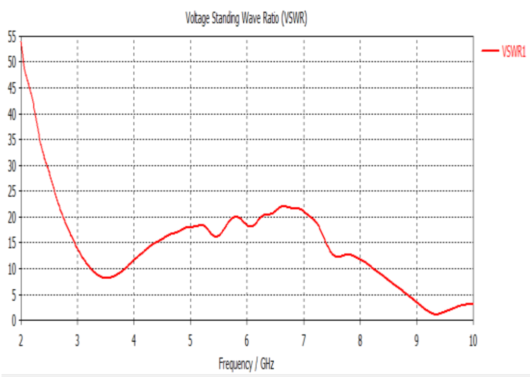

Fig. 3. VSWR for the designed antenna

C. *Antenna gain*

the plot for gain in frequency range 9 – 10 GHz is shown in figure (4). The designed antenna have a gain of 5.67 dB at 9.4 GHz.

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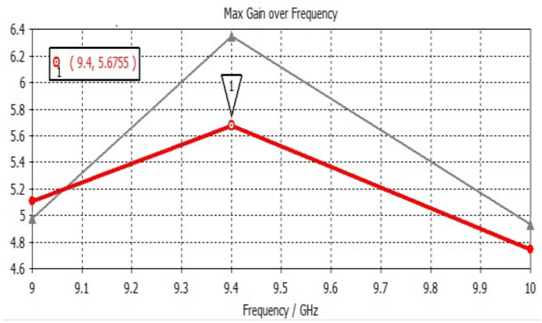


Fig. 4. Gain of the designed antenna

D. *Radiation Efficiency and Total Efficiency*

The radiation efficiency of the antenna defines that, how much power it can radiate from the input power given to it. The radiation efficiency at the 9.4 GHz is 92% and total efficiency is 87%, figure shows the radiation efficiency and total efficiency for the entire range of frequency.

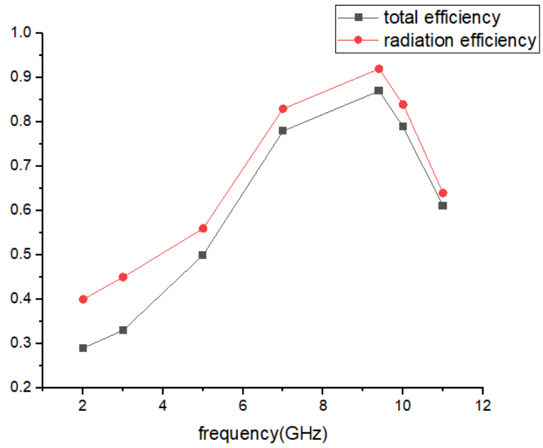
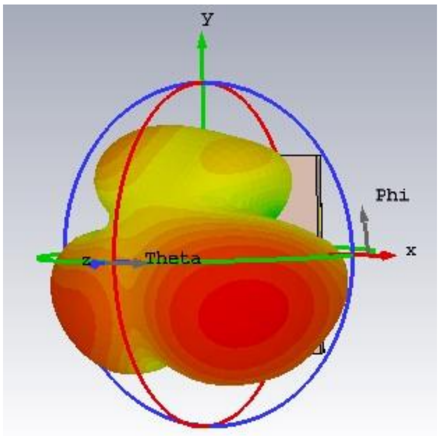


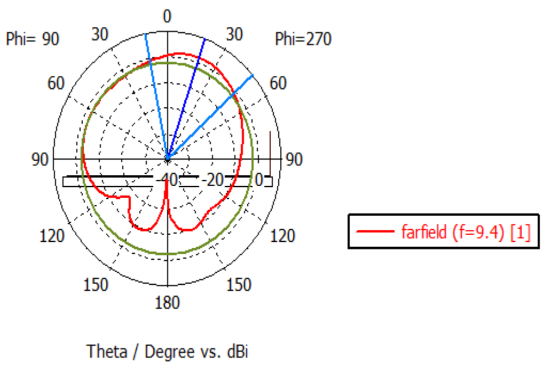
Fig. 5 radiation efficiency and total efficiency plot

E. *Radiation Pattern*

From the radiation pattern of antenna shown in figure,describes that the designed antenna is radiating mostly in the front direction and the designed antenna has stable radiation pattern.



(a)



(b)

Fig. 6. (a)Radiation pattern in 3D view,
(b) radiation pattern in polar graph.

V. CONCLUSION

The antenna designed is resonating in frequency 9.177 GHz to 9.557 GHz. Therefore, the required frequency of 9.4 GHz is achieved. That gives the maximum gain at the frequency of 9.4GHz. the VSWR of the antenna at the frequency of 9.4 GHz, is 1, i.e., there are no variations in the voltage, hence there is no reflections. The gain of the designed antenna is calculated as 5.67 dB. The radiation efficiency of the proposed antenna is 92% at the frequency 9.4GHz, the proposed rectangular MPA is perfectly suitable for the radar systems at the desired frequency of 9.4GHz.

Acknowledgement

The first author wishes to express their gratitude to the Rajasthan Technical University in Kota, India, for their assistance during the research project and the drafting of the paper.

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