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Design, Simulation & Analysis of Rectangular & Circular Microstrip Patch Antenna for Wireless Applications

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***Abstract*:While the revolution in antenna engineering leads to the fast-growing communication systems, Microstrip Patch Antennas (MPA) have proven to be the most unconventional discovery in the epoch of miniaturization. This paper incorporates the designing, simulation, and analysis of rectangular & circular microstrip patch antennas. The resonating frequency of the proposed patch antennas is 9 GHz, lying in the X band region and are designed on Rogers RT/duroid 5880 material having dielectric constant 2.2, using Ansys HFSS software.**

The proposed MPAs were compared on the basis of five performance parameters (Return loss, Bandwidth, VSWR, Gain and HPBW). It was observed that rectangular MPA has a higher value of return loss, VSWR and HPBW than circular MPA. Whereas, circular MPA has greater bandwidth and gain than rectangular MPA. The proposed antennas can be used in radar, wireless and satellite applications.

Keywords:Circular, rectangular, microstrip patch antenna, stripline feeding

I. INTRODUCTION

During the past few years, the urge for small antennas has expanded the attentiveness of researchers towards the scheming of microstrip patch antenna for wireless communication. Antennas are primarily specialized transducers that transform one form of energy (RF fields to AC: receiver antenna) to another (AC to RF fields: transmitter antenna) or conversely. Antennas are classified into various categories according to the physical structure and functionality.

An MPA has a base of ground plane over which a substrate having some relative permittivity of $€_r$ is there, which consists of a patch that could be of any shape and size. These antennas are fabricated using microstrip techniques on a printed circuit board (PCB) and are mostly operated at microwave frequencies. They not only have an advantage of being small in size, but also their ease of fabrication, low cost, lightweight, and conformity have increased their use extensively. Microstrip patch antennas have progressively emerged themselves in various RF fields. [1].

The type of MPA is determined by the patch which could be of any shape, most likely to be of square, dipole, elliptical, rectangular, triangular and circular. But the most accepted microstrip patch antennas are circular and rectangular [2]. Feeding is used to excite the antenna. Amongst the various feeding techniques, microstrip line, coaxial probe feed, proximity coupling, and aperture coupling are in demand [3]. The technique which we have used is microstrip line feeding.

The circular and rectangular microstrip patch antenna is so well accepted because they offer linear and circular polarization, compatibility to array configuration, feed line flexibility and multiple frequency operation [4].

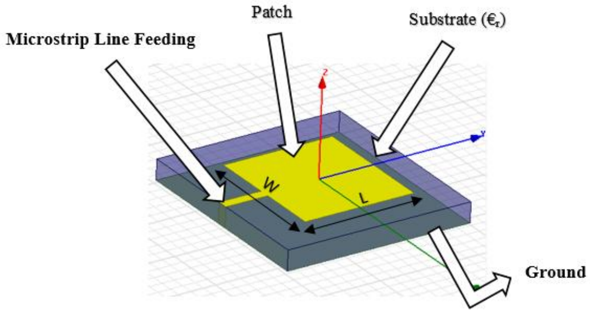

Fig. 1: Microstrip Patch Antenna.

II. RELATED WORK

In [2] different shapes of microstrip patch antenna were implemented using Ansoft HFSS. A multiband microstrip patch antenna was designed in [4] which covers a wide range of frequencies from 2 GHz to 9 GHz using a microstrip line feeding technique. This range of frequency is used for wireless and radar applications. [5] Include the designing of rectangular and circular microstrip fed antenna for Bluetooth application, operating at a frequency of 2.45 GHz. In [6] two different configurations of rectangular microstrip fed patch antenna parameters are analyzed at 9-15 GHz and 20-32 GHz frequency ranges, for 5G applications. The author in [7] has designed rectangular and circular MPA for 5G applications for a particular frequency of 28.5 GHz. Better results were obtained for rectangular MPA as compared to circular MPA. In [8] designing of circular sector antenna for C-band (4 GHz-8GHz) is achieved along with their comparison. They have concluded that resonance frequency and radiation pattern do not change with change in feeding technique. But the antenna nature can be altered by using different substrates. In [9] major study is done to scrutinize the effect of dielectric superstrates on various parameters.

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The study concluded that the frequency of the antenna will move to the lower side and parameters of the antenna will alter if the superstrate is placed over the substrate.

Apart from various advantages of a microstrip patch antenna, it has some limitations as well like, narrow bandwidth and low gain [1]. Wideband could be achieved by some modifications in the size of patch or by inserting slots [10-12]. Whereas, high gain could be achieved by using different feeding techniques [13].

III. PROPOSED ANTENNA DESIGN

A. Antenna Patch Dimensions

1)Rectangular Patch Antenna

Length (*L*) and width (*W*) of the rectangular microstrip patch antenna can be calculated from the given formulas [14],

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\epsilon r + 1}}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

$$\Delta L = \frac{0.412(\epsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{w}{h}+0.8)}$$

$$L_{eff} = \frac{C}{2f\sqrt{\epsilon_{reff}}}$$

$$L = L_{eff} - 2\Delta L$$

2) Circular Patch Antenna

The radius (*a*) of circular microstrip patch antenna can be calculated from the given formula [14],

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}}$$

Where,

$$F = \frac{8.791 \times 10^9}{f_r\sqrt{\epsilon_r}}$$

Here,

W = Width of rectangular patch,

L = Length of rectangular patch,

ΔL = Extension length,

L_{eff} = Effective length,

ϵ_{reff}= Effective dielectric constant,

h = Substrate height,

a = Radius of patch,

c = Velocity of light in free space,

ϵ_r = Dielectric constant,

f_r= Resonant frequency.

B. Antenna Design Parameters

The rectangular and circular shaped microstrip fed patch antennas were designed using High-Frequency Structure Simulator (HFSS) software. The proposed antennas are designed on a substrate having thickness '*h*' and relative permittivity '*€r*'. The optimized parameters of the proposed antennas are given in Table A..

TABLE A: List of Design Parameters

Parameters	Rectangular MPA	Circular MPA
Resonating Frequency, f_r	9 GHz	9 GHz
Patch Size	Length, L = 9.9 mm Width, W = 11.6 mm	Radius, a = 6.25 mm
Substrate Height, h	1.6 mm	1.6 mm
Dielectric Constant, ϵ_r	2.2	2.2

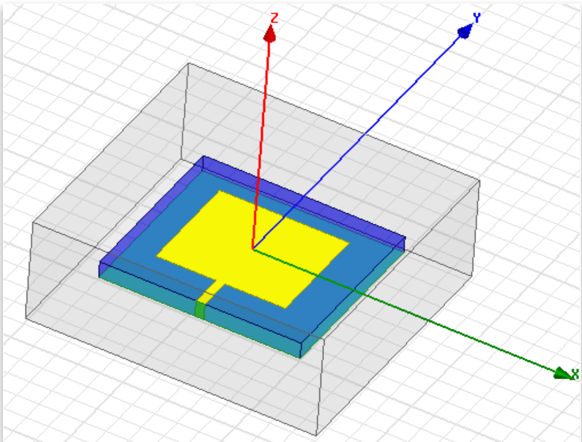

Fig. 2: Proposed Rectangular MPA with Microstrip Line Feeding Technique.

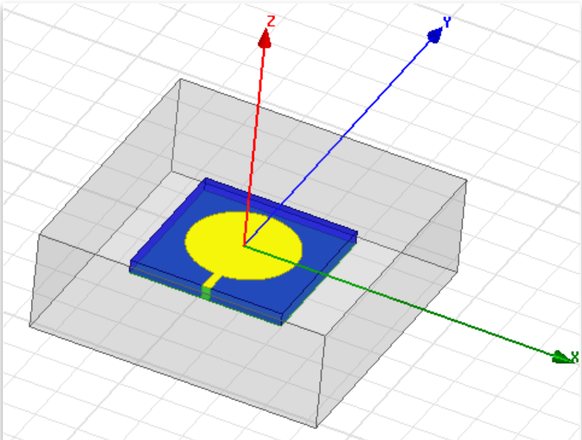

Fig. 3: Proposed Circular MPA with Microstrip Line Feeding Technique.

IV. SIMULATION RESULTS AND COMPARISON

The return loss of both types of proposed antennas are shown in Fig. 4 & Fig. 5. From both the graphs it can be inferred that rectangular shows the return loss of -24.16dB, whereas, circular has a return loss of -21.69dB. Hence, a better return loss of 2.47dB can be seen in the proposed rectangular MPA.

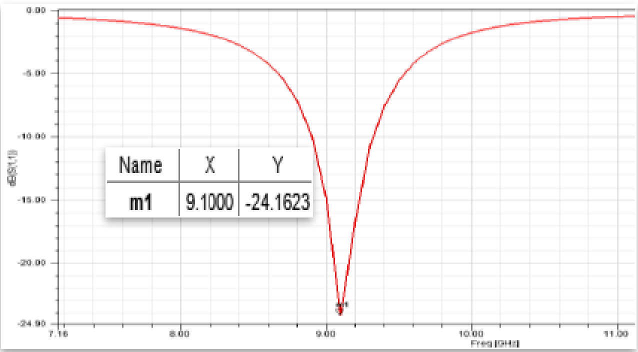

Fig. 4: Return Loss response of Rectangular MPA.

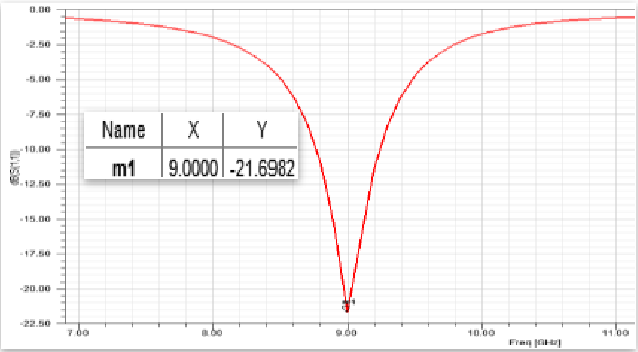

Fig. 5: Return Loss response of Circular MPA.

Fig. 6 & Fig. 7 shows the VSWR plot for circular and rectangular MPA respectively. The conclusion which can be drawn from both the plot is that the circular has a greater value of VSWR of 1.43 than the rectangular having VSWR of 1.07. Ideally, the value of VSWR should be equal to 1. This means, that the proposed rectangular MPA is much closer to the ideal value.

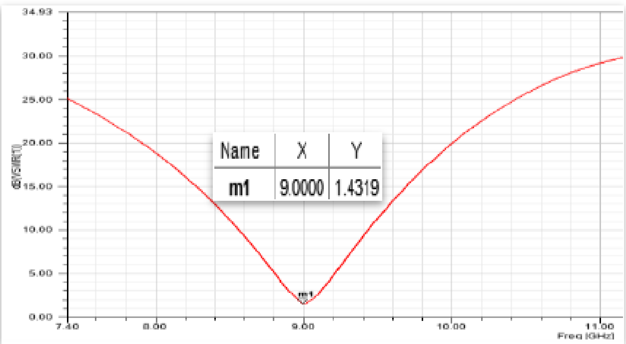

Fig. 6: Plot of VSWR of Circular MPA.

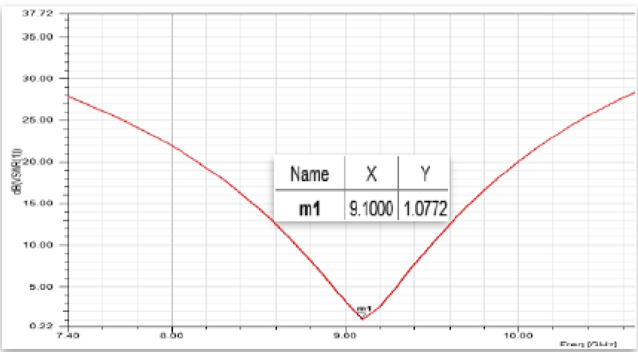

Fig. 7: Plot of VSWR of Rectangular MPA.

Fig. 8 & Fig. 9 gives the bandwidth of circular and rectangular microstrip patch antenna respectively (on considering -10dB values of frequency). Using simple calculation the bandwidth was calculated for both the proposed antennas. It was inferred that the bandwidth of circular MPA is 474.3 MHz, whereas, the bandwidth of rectangular MPA is 425.2 MHz which means 10% more bandwidth is achieved in the case of proposed circular MPA.

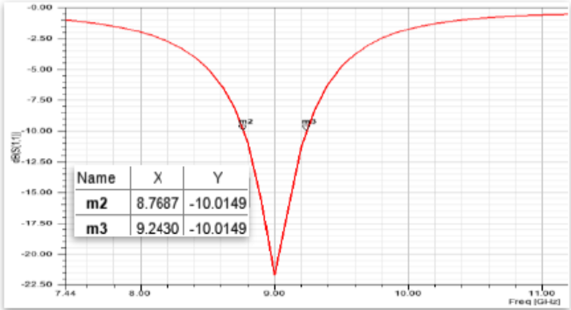

Fig. 8: Bandwidth calculation for Circular MPA.

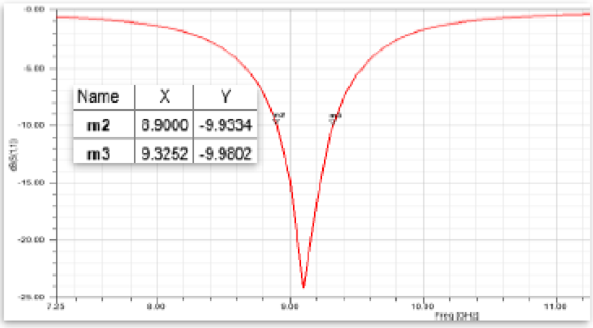

Fig. 9: Bandwidth calculation for Rectangular MPA.

Fig. 10 & Fig. 11 shows the gain of the proposed rectangular & circular MPA respectively. From the graph it can be deduced that circular has a greater gain of 7.3dB than rectangular MPA, having a gain of 6.9dB.

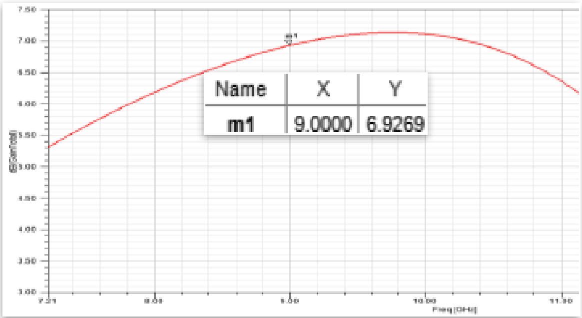

Fig. 10: Gain of Rectangular MPA.

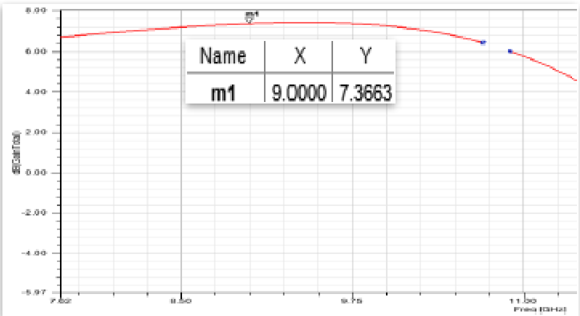

Fig. 11: Gain of Circular MPA.

Fig. 12 & Fig. 13 shows the pattern of radiation of the proposed circular and rectangular MPA. Half power beamwidth (HPBW) i.e., the angular beamwidth at 3dB of the circular microstrip patch antenna is lower (77.48 degrees), than the rectangular microstrip patch antenna having HPBW of 80.16 degrees.

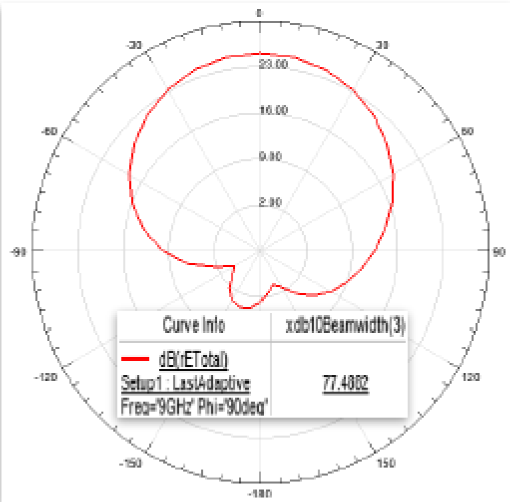

Fig. 12: Pattern of Radiation of Circular MPA.

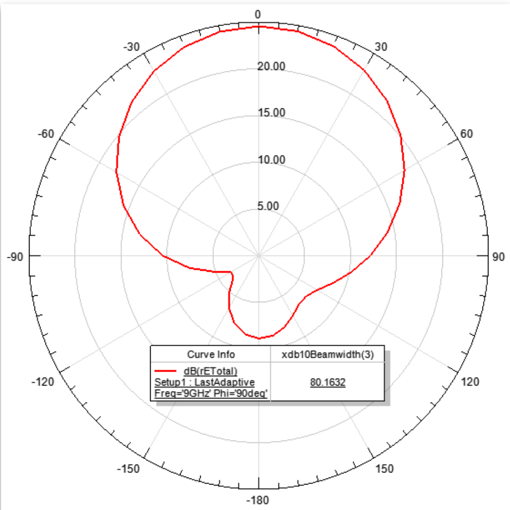

Fig. 13: Pattern of Radiation of Rectangular MPA.

The calculated and observed values of all the five parameters of the proposed circular and rectangular MPA are summarized in Table B. If return loss, VSWR and HPBW are taken into consideration, then supremacy of rectangular over circular microstrip patch antenna can be seen. Whereas, from the perspective of bandwidth and gain, circular seems to be dominating over rectangular MPA.

TABLE B: Analogy of Various Parameters of Performance

Performance Parameters	Circular MPA	Rectangular MPA
Return Loss	-21.69 dB	-24.16 dB
Bandwidth	474.3 MHz	425.2 MHz
VSWR	1.43	1.07
Gain	7.3 dB	6.9 dB
HPBW	77.48 degree	80.16 degree

V. DISCUSSION

The proposed rectangular and circular MPA not only have an advantage of being small in size but also have good and improved values of return loss, VSWR and HPBW when compared with previous research for X-Band [15]. As both bandwidth and resonating frequency are inverselyproportional to the value of dielectric constant, we have used a very low value of dielectric constant ($€_r = 2.2$) for substrate, so as to make it work for a frequency of 9 GHz. Also for better gain, return loss and bandwidth, a small thickness substrate is taken (h = 1.6mm), which also makes the proposed antenna compact in size. Hence, within the possible limitations, we have designed the best antennas meeting all the prior specifications. The proposed antennas can also be used in wireless, satellite & radar applications.

VI. CONCLUSION

Design, simulation, and comparison of circular and rectangular MPA using microstrip line feeding technique for a frequency of 9 GHz is proposed in this paper. This is achieved with the help of a software named HFSS. Both the proposed antennas show good results for return loss, bandwidth, VSWR and beamwidth. The study concluded that when return loss, VSWR and HPBW is considered, rectangular patch antenna shows superiority over circular patch antenna. However, from the perspective of bandwidth and gain, circular seems to be dominating over the rectangular patch antenna.

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