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X-BAND Rectangular Microstrip Patch Antenna: Design, Simulation, and Analysis

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Abstract: Microstrip Patch Antennas (MPA) have shown to be the most unusual finding in the era of downsizing, despite the fact that the revolution in antenna engineering has led to the rapidly expanding communication networks. The design, modeling, and analysis of rectangular microstrip patch antennas are all included in this study. The suggested patch antennas' resonating frequency is 9 GHz, which falls inside the X band area. Ansys HFSS software was used to design them using Rogers RT/duroid 5880 material, which has a dielectric constant of 2.2.

Five performance metrics were used to assess the suggested MPAs: return loss, bandwidth, VSWR, gain, and HPBW.

The requested information pertains to the measurements of return loss, voltage standing wave ratio (VSWR), and half power beamwidth (HPBW). The suggested antennas are suitable for use in radar, wireless, and satellite applications.

Keywords: Rectangular, microstrip patch antenna, stripline feeding.

I. INTRODUCTION

Researchers have been paying more attention to the design of microstrip patch antennas for wireless communication in recent years due to the growing need for compact antennas. Basically, antennas are specialized transducers that change energy from one form (RF fields to AC: receiver antenna) to another (AC to RF fields: transmitter antenna). Depending on their physical shape and intended use, antennas can be categorized into various of types.

The ground plane base of an MPA is covered by a patchy substrate with a relative permittivity of Ɛr. The patchy substrate may take on any form or size. These antennas are typically used at microwave frequencies and are created on printed circuit boards (PCBs) utilizing microstrip methods. Their tiny size is not their sole benefit; their simplicity of manufacture, affordability, lightweight nature, and conformance have all contributed to their widespread usage. In a variety of RF domains, microstrip patch antennas have gradually become more prevalent. [1].

The patch, which may have any shape but is most likely to be square, dipole, elliptical, rectangular, triangular, or circular, determines the kind of MPA. However, circular and rectangular microstrip patch antennas are the most often used [2]. The antenna is excited by feeding. Microstrip line, coaxial probe feed, proximity coupling, and aperture coupling are among the commonly used feeding methods [3]. We have used the microstrip line feeding technique.

The reason why the circular and rectangular shape microstrip patch antennas are so popular is that they provide various frequency operation, feed line flexibility, array design compatibility, and both gives linear or circular polarization [4].

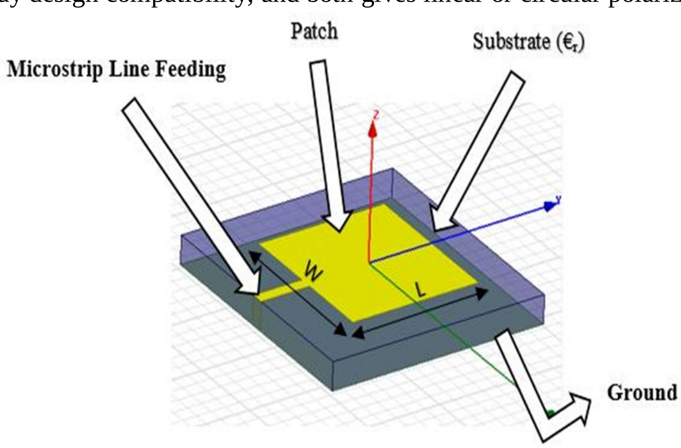

Fig. 1: Microstrip Patch Antenna.

II. PROPOSED ANTENNA DESIGN

A. Antenna Patch Dimensions

Rectangular Patch Antenna Length (L) and width (W) can be calculated from the given formulas [5],

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/2} \qquad (2)$$

$$\Delta L = \frac{0.412(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)} \qquad (3)$$

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \qquad (4)$$

$$L = L_{eff} - 2\,\Delta L \qquad (5)$$

Here,
W = Width of patch,
L = Length of patch,
ΔL = Extension length,
Leff = Effective length,
Ɛreff= Effective dielectric constant,
h = Substrate height,
Ɛr = Dielectric constant,
fr= Resonant frequency.

B. Antenna Design Parameters

High-Frequency Structure Simulator (HFSS) software was used for designing the rectangular microstrip-fed patch antennas. The substrate on which the suggested antennas are developed has a thickness of 'h' and a relative permittivity of 'Ɛr'. Table.1. lists the optimum settings for the suggested antennas.

Table. 1. List of Design Parameters

Parameters	Rectangular MPA
Resonating Frequency, fr	9 GHz
Patch Size	Length, L = 9.9 mm Width, W = 11.6 mm
Substrate Height, h	1.6 mm
Dielectric Constant, Ɛr	2.2

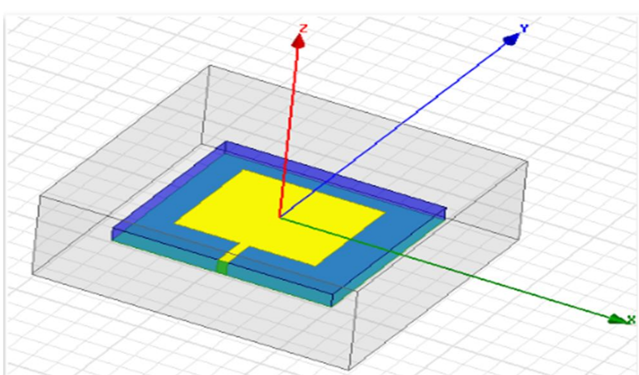

Fig. 2: Proposed Rectangular MPA with Microstrip Line Feeding Technique.

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III. SIMULATION RESULTS AND COMPARISON

Fig. 3 shows the return loss of Microstrip patch antenna. The figures shows that the rectangular shape exhibits a return loss of -24.16dB.

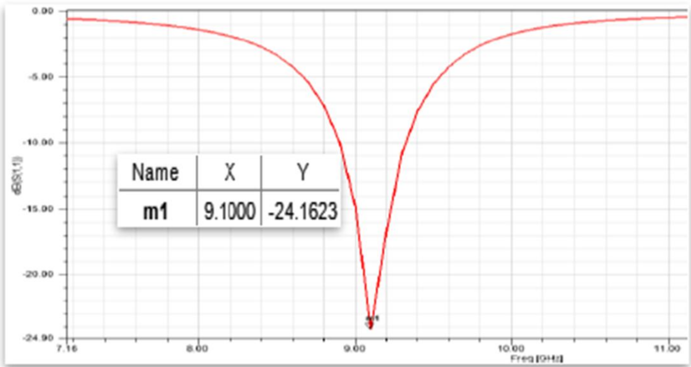

Fig. 3: Return Loss response of Rectangular MPA.

The VSWR plot for the rectangular MPA with a VSWR of 1.07 is seen in Figure 4. In a perfect world, VSWR would equal 1. This indicates that the suggested rectangle MPA is a lot nearer to the optimal amount.

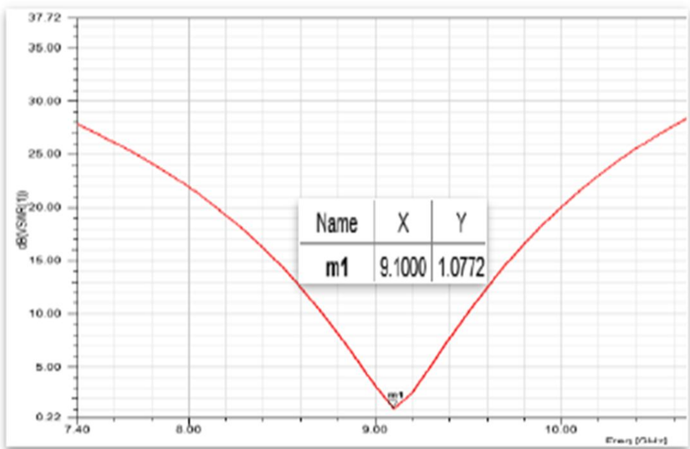

Fig. 4: Plot of VSWR of Rectangular MPA.

The bandwidth of a rectangular microstrip patch antenna (-10dB frequency values) is shown in Fig. 5. For the suggested antennas, the bandwidth was computed using simple calculations. The bandwidth of the rectangular MPA was calculated to be 425.2 MHz.

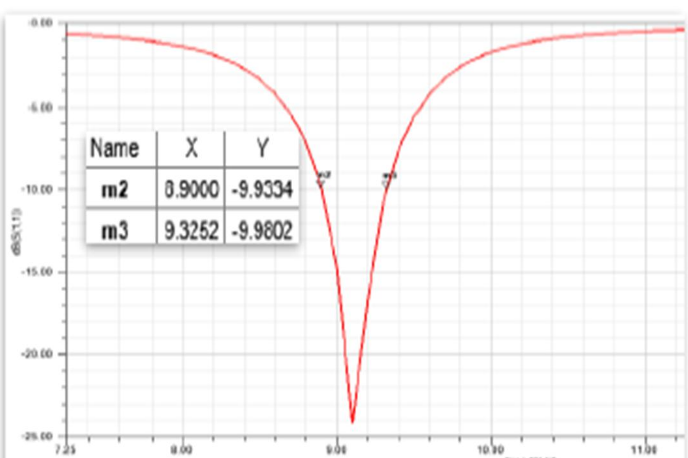

Fig. 5: Bandwidth calculation for Rectangular MPA.

The suggested rectangle MPA's gain is shown in Fig. 6. The graph indicates that the rectangular MPA has a 6.9dB gain.

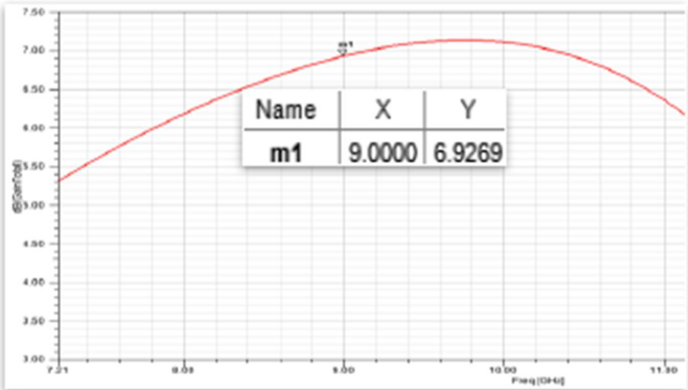

Fig. 6: Gain of Rectangular MPA.

The radiation pattern of the suggested rectangular MPA is depicted in Fig. 7. The rectangular microstrip patch antenna's half power beamwidth (HPBW), or angular beamwidth at 3dB, is 80.16 degrees.

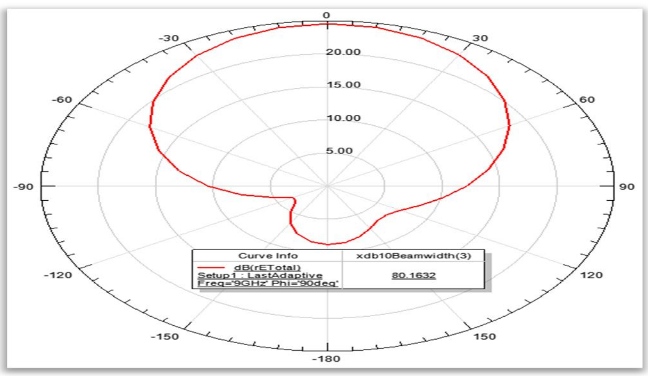

Fig. 7: Pattern of Radiation of Rectangular MPA

Table.2. provides a summary of the observed and computed values for each of the five parameters of the suggested rectangular MPA. The suggested rectangular MPA performs well in terms of VSWR, HPBW, and return loss. When it comes to gain and bandwidth, however, there is room for improvement.

TABLE.2. Parameters of Performance

Performance Parameters	Rectangular MPA
Return Loss	-24.16 dB
VSWR	1.07
Bandwidth	425.2 MHz
Gain	6.9 dB
HPBW	80.16 degree

IV. DISCUSSION

In addition to its modest size, the suggested rectangular MPA has good and improved return loss, VSWR, and HPBW values when compared to earlier X-Band research [6]. To make it function for a frequency of 9 GHz, we have chosen an extremely low value of dielectric constant (Ɛr = 2.2) for the substrate because both bandwidth and resonating frequency are inversely proportional to the dielectric constant value.

Furthermore, a thin substrate (h = 1.6 mm) is used for improved gain, return loss, and bandwidth; this also results in a small, compact antenna size. As a result, we have designed the best antennas that exceed all previous requirements while staying within any practical limits. The suggested antennas can be applied to radar, satellite, and wireless systems.

V. CONCLUSION

This work proposes the design and simulation of a X-band rectangular MPA operating at a frequency of 9 GHz utilizing the microstrip line feeding technology. This is achieved with the help of software named HFSS. According to the study's findings, the suggested rectangular microstrip patch antenna performs better in terms of return loss, VSWR, and HPBW than it does in terms of bandwidth and gain.

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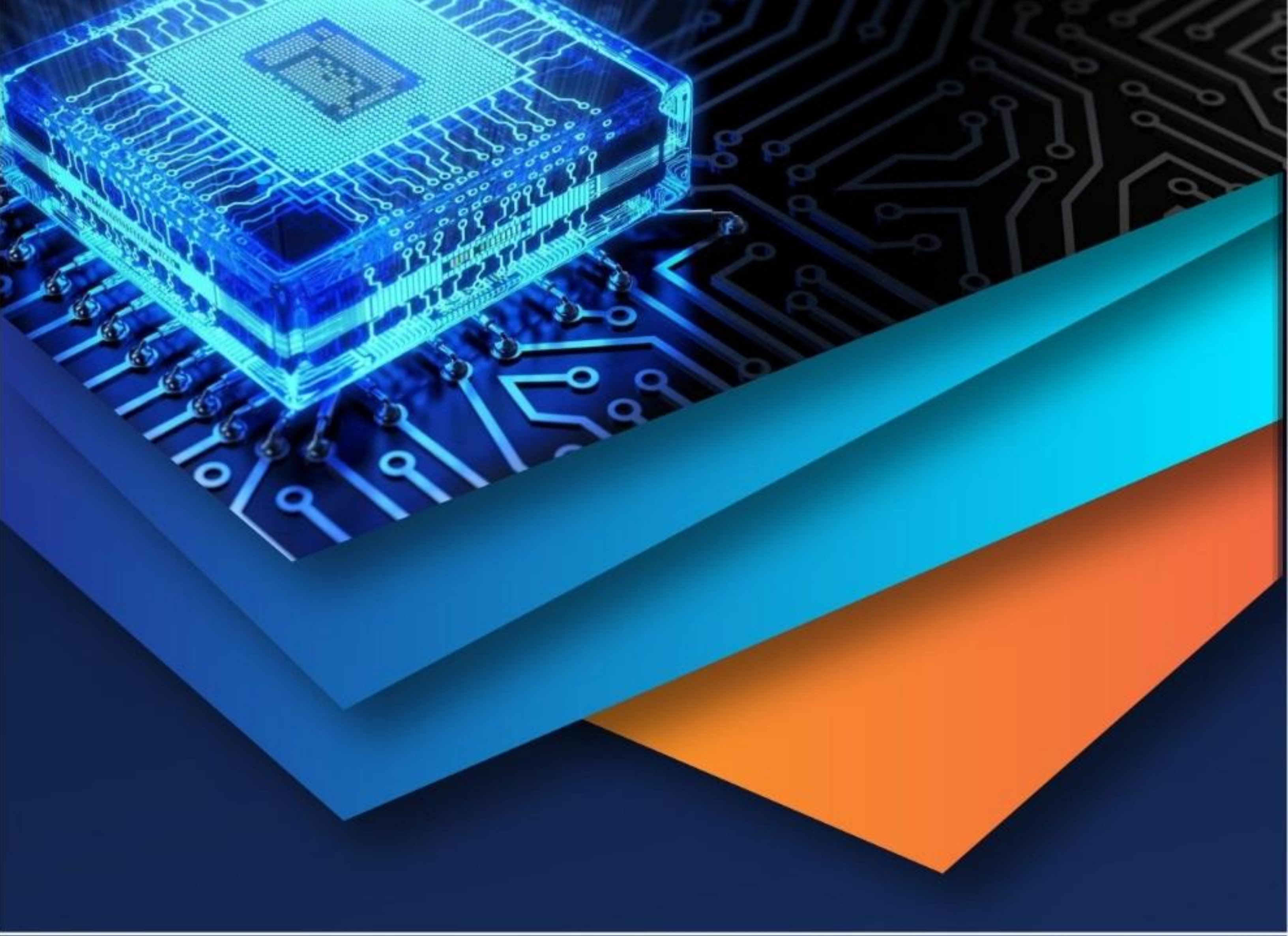

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