An S-Band Microstrip Patch Antenna Design and Simulation for Wireless Communication Systems

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ABSTRACT

In this paper, a 3.5 GHz microstrip patch antenna for the future of wireless communication is designed and studied. As the substrate material, Rogers RT/Duroid 5880 is utilized. This material has a thickness of 0.077 mm and a dielectric permittivity of 2.2. The proposed antenna layout is simulated using the CST Studio suite of software programs. This research aimed to get a lower return loss, a higher gain, a lower VSWR, better directivity, and more efficient operation. The simulation revealed that the return loss, gain, VSWR, and directivity were correspondingly -13.772 dB, 7.55 dB, 1.5152, and 8.43 dBi. The efficiency was 89.56%. This antenna has been designed and tested in various wireless communication applications. It has an operating frequency of 3.5 GHz. It is used as a reference antenna in communication satellites, weather radar, surface ship radar, wireless LANs (802.11b and 802.11g), multimedia applications in mobile TV and satellite radio, optical communications at 1460 to 1530 nm wavelength, and other wireless fidelity applications.

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1. INTRODUCTION

Wireless systems have grown significantly over time. A wireless communication system needs an antenna to send and receive data using electromagnetic waves. Because of this, more wireless devices are being used because communication technology is improving [1]. As a result, the next generation of wireless communication systems will provide even higher data rates and capacities over time. An antenna is an essential part of the wireless communication system. A metal device sends and receives information through radio waves [2]. The microstrip antenna is the most common type of antenna used in telecommunications, but it has many problems, such as a narrow bandwidth and low radiation efficiency [3]. It has several advantages, such as being lightweight, low cost, etc.

Microstrip patch antennas are increasingly important in developing modern wireless communication systems. It is mainly because more and more people want to use different wireless applications. Researchers and scientists have been working in this area because there are many ways to use wireless technology. The overall shape of a patch antenna is displayed in Figure 1 [4]. Antennas made of microstrip patches play an essential part in wireless communication. This device has a ground plane, a dielectric substrate, and a thin metallic patch of copper or gold. This design isolates the patch and the ground plane from the dielectric substrate. Patch antennas come in many shapes, such as circular, rectangular, square, elliptical, triangular, and dipole [5]. The circular and rectangular configurations are the two most typical forms that microstrip antennas take. These two patch antennas are utilized in the most difficult and demanding applications, particularly wireless ones.

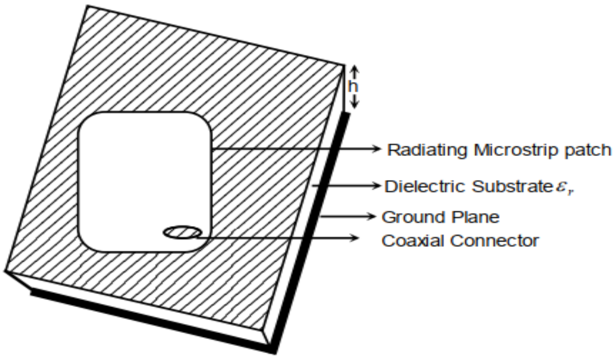

Figure 1. Microstrip patch antenna's geometric configuration.

The paper is divided into five parts to organize the presented information better. In addition, the report's organization consists of the following components: In Chapter I, the introduction is given. In Chapter II, a literature review is given. In Chapter III, antenna design and simulation are talked about. Results analysis is also discussed in Chapter IV. Finally, in Chapter V, the conclusion is given. The next chapter will have all of the references for this section.

2. LITERATURE REVIEW

Microstrip patch antennas, more commonly called MSA, are used a lot in wireless communication because they are cheap, easy to make, and can produce both linear and circular polarization. Numerous researchers have focused on MSA research due to these benefits [6]. The main goal of this research is to make the MSA have a more comprehensive range of impedance [3]. In the scope of this study, a low-profile wideband E-shaped microstrip patch antenna for Wi-max applications is proposed. The microstrip feeding method was used to create this proposed antenna to function correctly. It uses the effects of patch stacking and partial grounding together, which makes its bandwidth even better.

The design and manufacturing of a microstrip line-fed aperture coupled patch antenna operating at 10 GHz are presented in this study [7]. The suggested antenna is a communication system that operates on the X-band and includes scaled variants that operate at lower frequencies. This article offers a microstrip patch antenna that has a rectangular shape and is intended for use in wireless applications [8]. The main goal of this microstrip patch antenna is to improve gain, directivity, and bandwidth. It works with both S and C frequency bands. For this study [9], a microstrip patch antenna with a frequency of 2.4 GHz was built and studied as a possible future technology for wireless communication. This study aimed to produce a minor return loss, a more significant gain, and a lower voltage standing wave ratio (VSWR).

This work shows and builds [10] design and evaluate the performance of elliptical microstrip patch antennas operating at 3.5 GHz for 5G applications. This study will compare the performance of these antennas with and without a slot. For the 3.5 GHz wireless 5G band, an analysis was done on three designs of compact size, cost-efficient, wide-band microstrip patch antennas utilizing FR-4 substrate with adequate dimensions. This article talks about [11], how a 5G broadband wireless microstrip patch antenna could be used. At 3.5 gigahertz, the single-element antenna was intended to function within the priority-1 spectrum. The main objective of the antenna was to increase the return loss, achieve a standard VSWR and obtain a suitable bandwidth, which will be used for 5G wireless applications.

In this paper [12], design, and simulation, a rectangular microstrip patch antenna is fed from the inside. This will be our primary focus. So, a unique particle swarm optimization method based on IE3D was used to make a linearly polarized inset feed and a rectangular microstrip patch antenna with an array of four elements. It's a significant quantity that controls the antenna's resonance frequency. The length of the antenna is approximately half the length of a wavelength in the dielectric medium it's made of, in light of the planning and decision-making that went into the width and height of the patch and the depth of the feed line. The antenna started as a single patch, but after looking at its operation frequency, radiation patterns, reflected loss, efficiency, and gain, we decided to change it to a 2x1 linear array instead. The last thing that was looked at was how to increase the directivity, growth, efficiency, and radiation patterns of the 4x1 linear antenna array. As part of this research [13], a low-profile patch antenna was used in 5G communication systems. For 5G, the resonating frequency has been set at 3.5 GHz. The substrate has dimensions of 25.2 by 48 millimeters square. The main radiating patch is in the shape of an ellipse, made with the line feed method. The simulation is carried out by the program known as CST Microwave Studio. Several characteristics have been measured, including the S-parameter, antenna gain, directivity, and efficiency. The antenna has a gain of more than 5 dB, which makes it an excellent choice for many types of communication. Applications that require 5G connectivity are the focus of the antenna's design.

Microstrip antennas operating at 3.5 GHz and designed for usage in fifth-generation (5G) applications were developed and tested as part of this research article [14]. The needed parameters were determined using Huawei's public policy stance, Qualcomm's general policy stance, and an article from the Rel-15 3rd Generation Partnership Project (3GPP). Because microstrip antennas have a narrow bandwidth, certain adjustments must be made. These include proximity-coupled feeding and a defective ground structure (DGS). The first step is to calculate the initial dimension of the antenna; the final step is to simulate and optimize the antenna. The simulation begins by replicating the starting dimension. Next, proximity-coupled feeding is applied, and finally, the DGS is utilized until the required antenna is obtained.

This study presents [15] the design analysis of microstrip antennas with rectangular and square-shaped feedlines. Microstrip lines feed these microstrip antennas. The square-shaped microstrip antenna provides a greater bandwidth while maintaining an adequate return loss than the rectangular microstrip antenna. The microstrip antenna in the square shape proposed with a short feedline has greater bandwidth. Many wireless applications could benefit from having access to such good bandwidth and a high return loss. These article shows [16] how to design and analyze a rectangular microstrip patch antenna used in different wireless and broadband communication applications. This antenna was made and tested for use in several wireless communication systems at 5.2 GHz.

3. ANTENNA DESIGN AND SIMULATION

Figure 2 shows a simulation run on the MPA performed with CST software. The CST program that models the antenna design can show the antenna's return loss, VSWR, gain, directivity, radiation pattern, and efficiency, among other things. Using these antenna parameters, a summary of the results of the simulated antenna designs for the designed MPA is shown and discussed below. This is to analyze and evaluate the antenna performance of the proposed antenna design. This will be done in the following paragraphs.

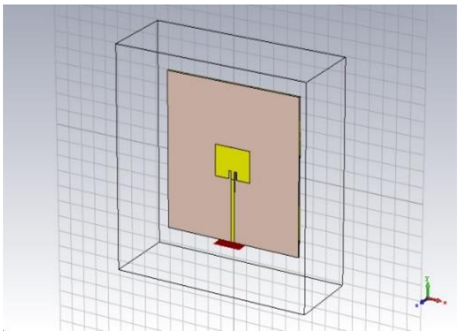

Figure 2. Antenna the design of antenna in CST

3.1. Antenna Parameter

The results of the measurements taken of the antenna can be found in Table 1 below. The notation Wg is used to express the width and length of the ground, whereas the note Lg is used to denote the size. In addition, the height of the substrate (H_S) and the thickness (t), as well as the width and length of the antenna patch (Wp and Lp), are provided. Other parameters stand in for the values of the many components that make up the whole.

Table 1. Optimized Dimensions of the Antenna

W_g	L_g	W_p	W_L	H_g	ε	t
100	100	33	28.46	1.6	2.2	0.077

3.2. Return Loss

Based on the simulation's final results, the parameter was accurate. The base value is -10 dB, which is ideal for mobile or wireless technology. The antenna is tuned to the required frequency to function correctly. Figure 3 depicts various S-parameter values. Among them, -13.772 was the best value. As can be seen in Figure 4, it runs at a frequency of 3.5 GHz. The return loss was measured at -13.772 decibels (dB) at this frequency. The antenna's bandwidth can be determined by measuring the distance between two junctions, which come in at 3.4903 and 3.5139 GHz, respectively. Figure 4 demonstrates that the antenna has a bandwidth of 0.0236 GHz.

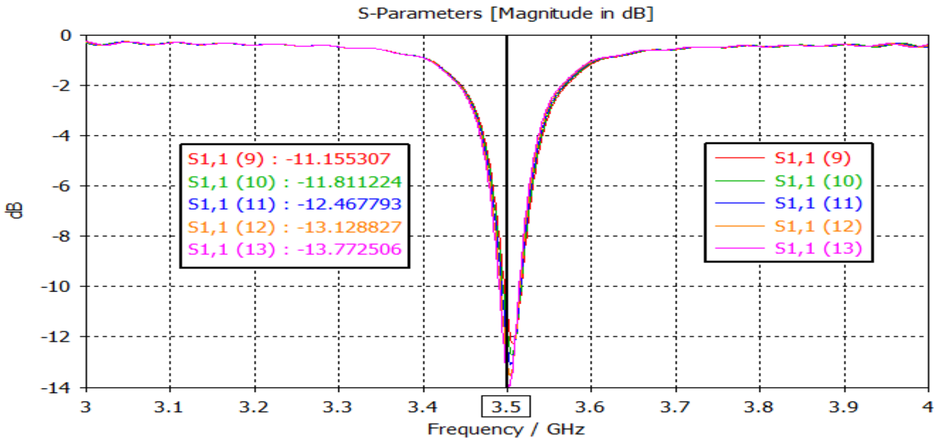

Figure 3. Graph of frequency versus return loss of gap inset feed

In Figure 4, the return loss (dB) versus frequency illustrates that the suggested microstrip patch antenna has a return loss of -13.772 dB at its solution frequency of 3.5 GHz. This return loss value is far greater than what is desirable for improved performance.

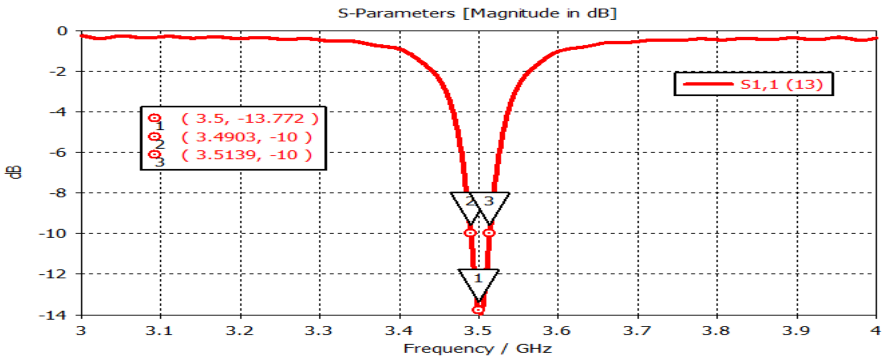

Figure 4. Simulator frequency vs. return loss.

3.3. VSWR and Bandwidth

The voltage standing wave ratio, or VSWR, is a measurement that shows how much power an antenna reflects. It is usually written as an abbreviation, though. It is recommended that the value of VSWR be a number that is both positive and actual. As the VSWR value drops, the antenna's performance improves. This helps to clarify how the impedance of the transmission line is matched. Figure 5 shows a plot of the designed simulated VSWR for the MPA. Therefore, the magnitude of the VSWR is less than two, which is within the acceptable range, and it is 1.5152 at 3.5 GHz. This range of frequencies spans 3.4891 GHz to 3.5150 GHz. Also, figure 6 illustrates the variation of the VSWR with frequency.

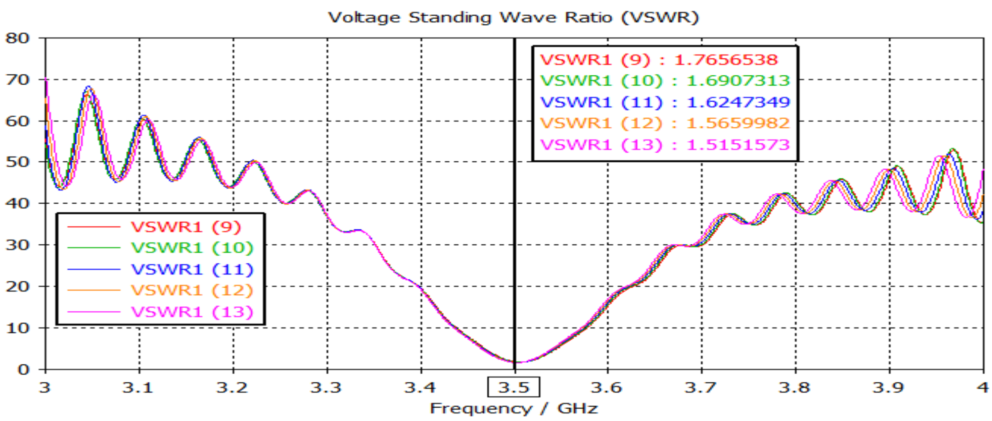

Figure 5. Graph frequency versus VSWR of simulation result.

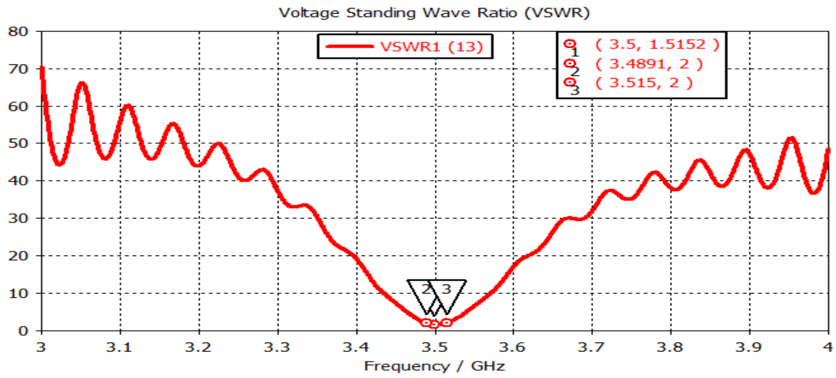

Figure 6. Graph frequency versus VSWR of simulation result.

3.4. Gain and Radiation Pattern

Figures 7 and 8 can determine in which order the antenna has maximum gain and the highest directivity. At 3.5 GHz, the antenna achieves its maximum gain of 7.55 dB. At 3.5 GHz, the directivity measures out to 8.43 dBi.

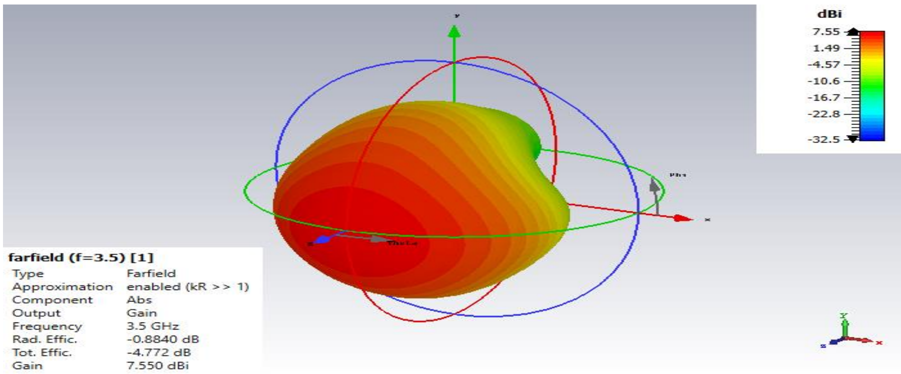

Figure 7. 3D gain field configuration of the MPA

The figure 8 illustrates one more parameter frequently utilized to characterize the MPA radiation pattern. At 3.5 GHz, the suggested patch antenna has an efficiency of 89.56% and a gain of 8.43 dBi, as seen here in the 3D radiation pattern of the antenna. These figures are for the antenna's different characteristics.

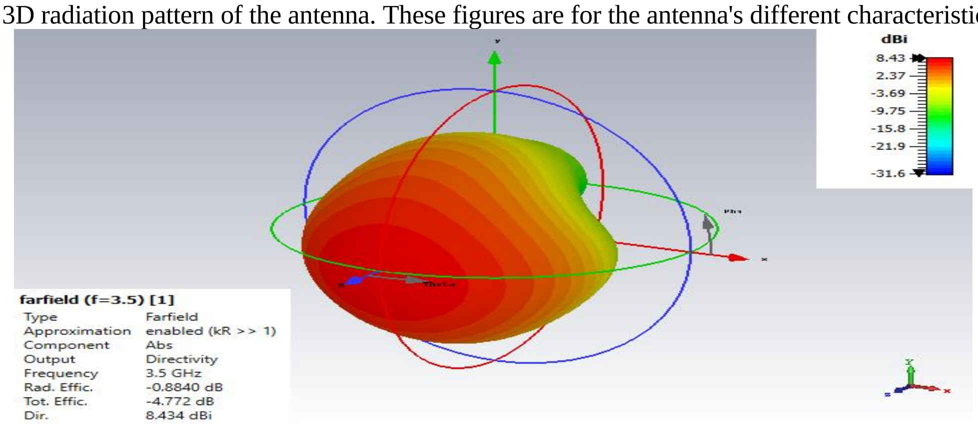

Figure 8. depicts the gain pattern in its polar form.

The primary lobe's magnitude is 7.56 dB, and its orientation is 3.0 degrees in this illustration. The angular breadth corresponding to three decibels (dB) is 72.5 degrees. The measurement comes in at -14.4 dB for this antenna's sidelobe level. Figure 10 shows another way to look at the directivity pattern. It is shown in its polar form. The primary lobe's magnitude is 8.44 dBi, and its orientation is 3.0 degrees in this figure. 72.5 degrees is the width of the angle when measured in three decibels. This antenna has a level of sidelobe that is -14.4 dB when functioning correctly.

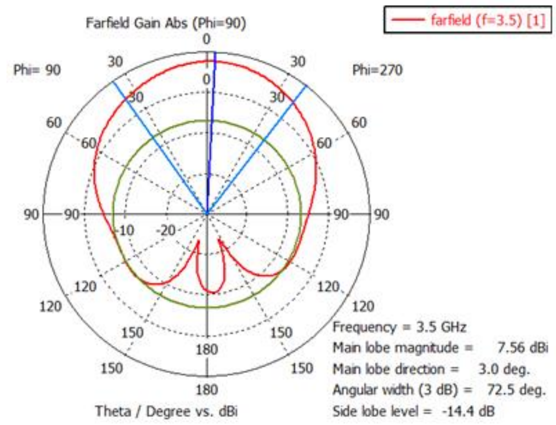

Figure 9.Farfield gain

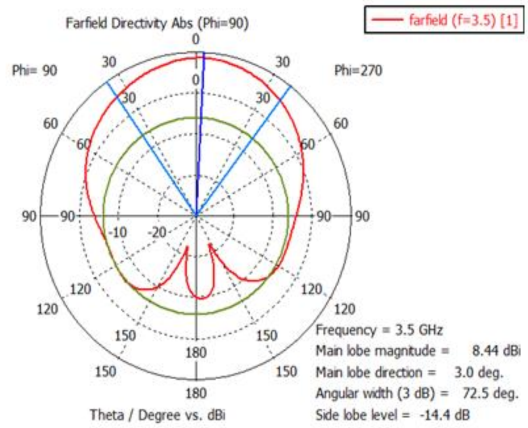

Figure 10. Farfield directivity

Table 2 provides a synopsis of the outcomes of the simulation. As seen in Table 2, the addition of slots to the design of the proposed antenna resulted in increases in the antenna's level of directivity and gains in bandwidth and gain.

Table 2. Summarizes the Simulation Results

Parameter	**Value**
Return Loss (dB)	-13.772dB
Bandwidth (GHz)	0.0236GHz
Gain (dB)	7.55dB
Directivity (dBi)	8.43dBi
Efficiency (%)	89.56%
VSWR	1.5152

4. RESULT ANALYSIS

In this section, the simulations' outcomes are discussed in the proposed MPA. This study examines some of the simulation findings for antenna parameter values. These results include bandwidth, VSWR, radiation pattern, beam width, and polarization. The suggested antenna has a maximum gain of 7.55 dB at a frequency of 3.5 GHz. This antenna has a return loss of -13.772 dB. This antenna's bandwidth is 0.0236 GHz, and its efficiency is 89.56%, which is pretty good. Researchers are beginning to focus on high-band antennas as a means of communication as the lower frequency band has gotten crowded. The antenna in question operates in the high band, boasts strong directivity, and performs admirably in terms of gain. As a result, this antenna could become an excellent option for wireless applications shortly.

The results of the experiments showed that the system worked well at a resonance frequency of 3.5 GHz when it was working. A simulation of the proposed design of MPA was run to test the antenna that was made with CST software. The maximum return loss, gain, directivity, efficiency, and bandwidth of the intended MPA are compared in Tables 3 and 5. There is a growing demand for wireless technology, which could be a good fit for that demand.

Table 3. Contrast between published antenna and planned design

Ref.	S_{11}(dB)	Gain	VSWR	BW(GHz)
[4]	-13.48	6.63	1.538	0.847
[8]	-18.27	4.46	2.13	0.2
[9]	-13.89	6.6	1.5	0.07
[10]	-41.3	4.45	1.01	1.13
[11]	-26.347	3.68	1.10	0.64
[14]	-17.436	6.6	1.31	65.2MHz
[18]	-19.61	6.58	1.82	10
[19]	-12.54	5.5	1.6	3.5
[20]	-17.43	3.019	1.31	0.5182
[28]	-15.62	7.2	-	-
[30]	-22.3073	6.08	1.3	3
[31]	-31.320	5.934	1.08	318.5MHz
[32]	–40.2827	5.8263	1.02	200 MHz
[33]	-23.673	6.801	2.00	13.83
[37]	-27.265	-	-	0.2523
This Work	-13.772	7.55	1.5152	0.0236

In table 4 discusses the substrate materials, and thickness of various previous papers. By studying the previous papers, it is known that different substrate materials (FR-4 substrate, Rogers RT/Duroid 5880) have been used for different applications. For which different values of loss tangent and thickness are available.

Table 4. Substrate materials used in different antennas, and their loss tangent and thickness are given different values.

Reference	Substrate Materials	Thickness
[8]	Roger RT/duroid 5870	3.17mm
[10]	FR-4 substrate	0.8mm
[11]	Rogers RT5880	
[12]	FR-4 substrate	0.035mm
[13]	FR4 epoxy	0.8mm
[17]	FR-4 substrate (lossy)	0.5 mm
[21]	Rogers RT5880	0.254 mm
[22]	Rogers RT 5880	0.5 mm
[23]	FR-4 substrate	1.59mm
[24]	FR4 substrate	0.8 mm
[25]	FR4 substrate	1.6mm
[26]	RT/Duroid 5880	0.254 mm
[27]	FR-4 substrate	1.6mm
[34]	Rogers RT 5880	0.5mm
[35]	FR-4 substrate	0.8mm
[36]	FR-4 substrate	0.8
[37]	FR4-epoxy	0.8mm
[38]	Rogers RT 5880	0.2mm
[39]	Rogers RT/Duroid5880	0.3451mm
This Work	Rogers RT 5880	0.077mm

Table 5. Comparasion between others design

Ref	Dielectric Permittivity (ε)	Efficiency (%)
[10]	2.2	89.17%
[11]	2.2	88.19%
[13]	4.3	-
[17]	4.3	84.81%
[22]	2.2	-
[29]	4.4	53.12%
[31]	4.3	81%
[32]	4.4	88.40%
[33]	6	-
[38]	2.2	85.71%
This Work	2.2	89.56%

5. CONCLUSION

This paper shows how a microstrip patch antenna (MPA) is made and looks at how well it works for fifth-generation wireless communication systems. The proposed MPA simulation results show that the return loss, gain, directivity, and VSWR are -13.772 dB, 7.55 dB, 8.43 dBi, and 1.5152, respectively. The proposed antenna offers highly competitive performance when weighed against other designs. Different antenna designs have improved broadband performance, gain, return loss, and radiation efficiency. So, the antenna made for this paper is a good candidate for use in wireless applications. The antenna with the new method can be used for WLAN, WiMAX, radar, and wireless satellite communications in the S-band area of wireless communications. The antenna that was made for this study is a single-band antenna. However, this work could make a multiband antenna that can work at many frequencies and be used for various purposes.

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