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For wireless LAN application, microstrip patch antenna design in S-band

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ABSTRACT

This article presents a 3.5 GHz rectangular microstrip patch antenna (RMPA) designed, studied, and analyzed for wireless LAN applications. Using Fr-4 as substrate material, whose dielectric permittivity is 4.3, patch thickness is 1.65 mm, and loss tangent is 0.025. A feeding line with an impedance of 50 Ω is utilized to supply the antenna with power. Computer simulation technology (CST) software has been used to design the antenna and origin pro software has been used to display the resulting figures from the simulation. The antenna simulation showed that the return loss is -56.82 dB; the directivity gain is 6.02 dBi, the bandwidth is 0.148 GHz, and the voltage standing wave ratio (VSWR) is 1.0028. The paper aims to increase the return loss, develop a standard VSWR, increase the directivity gain of the antenna, and improve the antenna bandwidth. The results of the proposed antenna were much better than previously published papers, which were suitable for wireless applications. This proposed antenna can be used for future wireless LAN applications.

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1. INTRODUCTION

In wireless communication, a microstrip antenna offers several advantages, including high efficiency, lightweight construction, low manufacturing costs, and a low profile. On the other hand, these antennas have a relatively narrow impedance bandwidth, which is the primary disadvantage. It has been suggested to use a wide variety of approaches and configurations in order to accomplish the goals of increasing bandwidth and decreasing size. A microstrip antenna is primarily made up of a metallic patch mounted on a dielectric thin substrate. It has been possible to increase the bandwidth by employing several strategies, such as hiring a thick substrate with a low dielectric constant and incorporating parasitic patches into the primary patch [1]. On the other hand, the typical microstrip antenna suffers from the primary limitations of having a restricted bandwidth and a poor gain. The patch antenna, on the other hand, may be modified to function at a variety of resonance frequencies, enabling it to be utilized for various wireless applications despite only requiring a single antenna. Microstrip patch antenna design can use various substrates with a dielectric constant between 2.2 and 12. A substrate with a low dielectric constant produces higher efficiency and a wider impedance bandwidth [2]. It is most commonly utilized in applications involving aircraft, spacecraft, satellites, and missiles because of its excellent performance capabilities, ease of installation, low cost, and compact size [3]. Microstrip patch comes in various shapes as shown in Figure 1, including rectangular, square, circular, triangle, dipole, and elliptical. Figure 1(a) rectangle, 1(b) square, 1(c) circle, 1(d) triangle,1(e) donut, and 1(f) dipole displays the multiple configurations that a microstrip patch antenna can take [4], [5]. In recent years, researchers have developed novel designs to improve the performance of patch antennas for use in various applications. Patch antennas have functions in many bands, achieving more strength, a wider bandwidth, and compactness due to these innovative designs.

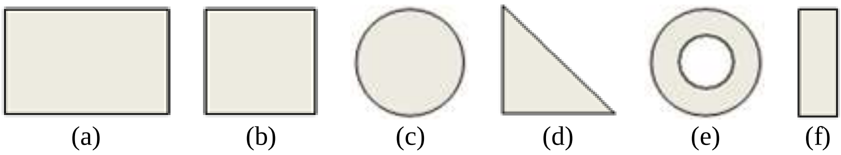

Figure 1. Representative shapes of microstrip patch elements; (a) rectangle, (b) square, (c) circle, (d) triangle, (e) donut, and (f) dipole [5]

The complete paper is organized into six sections. The introduction is discussed in section 1, the literature review is discussed in section 2, the material and method are discussed in section 3, the proposed antenna design and simulation results are discussed in section 4, the result analysis is discussed in section 5, and the conclusion is discussed in section 6. Later, the references to various papers are highlighted, and finally, the biographies of all the authors are mentioned.

2. LITERATURE REVIEW

In the 1950s, that was the first time a microstrip antenna was made available to the general public. Despite a modest beginning, it is still strong today [6]. It wasn't until the early 1980s that its development began to pick up momentum. Microstrip patch antennas with resonance frequencies in the frequency spectrum required for wireless use have been the subject of an increasing number of studies in recent years. The development of microstrip patch antennas is also receiving a considerable amount of attention and support at the moment. A wide range of articles on the subject of 3.5 GHz are discussed in the area that was just mentioned. Another topic discussed in that section is the numerous research gaps identified in previously published studies.

According to this study [7], the authors want to discuss how to design, simulate, build, and test a microstrip Yagi patch antenna that works on the 3.5 GHz band and is compatible with 5G technology. Wireless communication mobile systems are the source of the demand for radio frequency (RF) devices that are compact and fully integrated, low in cost, and small in dimensions due to the limited space and volume available within the radio device. Additionally, these devices must have a high degree of miniaturization and be able to operate within the crowded 5G NR sub-6 GHz bands.

For 5G operations [8], a low-profile microstrip antenna that maintains a steady radiation pattern throughout a relatively broad spectrum has been described. By integrating folded walls, it was possible to combine four resonant modes that operate at various frequencies into a single structure, resulting in an increase in bandwidth, steady gain, and excellent matching. The results of the measurements demonstrate that the suggested antenna has the benefits of regular radiation patterns, low cross-polarization, and low back lobes, displaying potential utility for the applications of 5G wireless communication systems. The proposed antenna also has an average gain of 5 dBi.

Faisal *et al.* [9] presents two compact, flexible coplanar waveguide (CPW)-fed antennas in the shape of flowers capable of being utilized for high-data wireless applications. The antenna's flexibility is characterized by taking measurements in three different configurations: flat, with a concave bend, and with a convex bend. The antennas in the shape of the proposed flowers are pleasing to the eye and work exceptionally well. The proposed antennas are suitable for use in high-data wireless applications as exterior antennas due to their low cost, visual appeal, compact size, wide bandwidth, and ease of integration.

Research by Ferdous *et al.* [10], a low-profile patch antenna for use in 5G communication applications was constructed. For the 5G application, the resonating frequency was 3.5 GHz. The primary radiating patch takes the form of an ellipse, and the technique known as line feeding is utilized. It has been possible to observe a variety of parameters, such as the S-parameter, antenna gain, directivity, and efficiency. The antenna has a gain greater than 5 dB, making it an extremely beneficial component for communication. Applications that require 5G connectivity are the focus of the antenna's design. A high-gain microstrip patch-type WiMAX antenna that works at 3.5 GHz was built in this study [11]. It has a parasitic radiator and a higher ground plane. The design of the antenna has been accomplished through the execution of numerous three-dimensional electromagnetic simulations. When a parasitic radiator is positioned above the patch antenna, there is a corresponding increase in gain. There was no longer a requirement for a radio-frequency amplifier due to the general improvement in growth.

Al-Gburi *et al.* [12] aims to create hexagonal microstrip patch antennas for use in wireless backhaul over a frequency range of 3.5 GHz and then evaluate their performance in simulation. A microstrip corporate feed line that produces directional radiation supplies the planned antenna with its radiation sources. The capability of the base station to provide high-quality and high-capacity network connectivity is beneficial as a result of this. In particular, this particular form of antenna is designed to be most effective for point-to-point communications that extend across significant distances. As a consequence of this, the bandwidth was raised. Given the overall performance of the antenna, it is clear that the hexagonal patch antenna that has been designed is suitable for use in 5G communication operations.

Azeman *et al.* [13] examines, the design of a patch antenna operating at 2.4 GHz and 3.5 GHz resonance frequencies and reports its findings. Comparisons were made between the two antennas' properties, such as return loss, radiation pattern, surface current, and directivity or gain, among other things. In addition, the optimization of patch measurement to reach the sought-after resonant frequency was discussed. Ezzulddin *et al.* [14] shows how to test various microstrip antenna shapes, including square, circle, and triangle patches, using finite integration techniques (FIT) and the finite element method (FEM). These patch shapes can be made in real life, and the gain, bandwidth, voltage standing wave ratio (VSWR), return loss, directivity, and radiation pattern of the microstrip antenna were looked at to see which method works best.

Research by Prabha *et al.* [15], discusses and analyzes the design of microstrip patch antennas for wireless communication applications. The patch antenna that was designed is suited for use in WiMAX applications that run at 3.55 GHz. These applications are intended to deliver high-speed data rates and internet access to a wide coverage area. When this study looked at performance, the square patch design did better than the rectangular patch design in reducing noise, increasing gain, and directing the signal. According to research by Abdulbari *et al*. [16], a microstrip patch with a T-shaped rectangular antenna is operating. For 5G applications, the T-shaped patch works at a resonant frequency range of 3.6 GHz. A discussion is had on the properties, including radiation pattern, reflection coefficient, gain, current distribution, and radiation efficiency. The frequency band is associated with mobile applications utilizing 5G technology.

In this article [17], a revolutionary microstrip rectangular patch antenna with dual trapezoidal slots and a frequency of 3.5 GHz is constructed. The antenna will operate at that frequency. The microstrip patch antenna that has been proposed is utilized for a variety of wireless applications in the frequency range of 2-4 GHz that falls inside the S-band. Based on the findings, it has been determined that the proposed patch antenna with dual trapezoidal slots has improved return loss and VSWR. Therefore, it is suitable for use with WiMax application services. According to research by Chowdhury *et al.* [18], researched a unique planar rectangular slot antenna designed and fabricated for 5G wireless applications. An E-shaped and rectangular radiating slot, an inverted stub, a microstrip feed line with a two-folded T-shaped design, and a circular parasitic element on the upper side of the antenna are the components that make up the antenna. Using a microstrip feed line; each of these characteristics is activated simultaneously. Furthermore, it possesses a fair reflection coefficient and great impedance-matching qualities. To summarise, the antenna that has been proposed is an attractive choice for usage in wireless applications that implement 5G technology.

Hasan *et al.* [19], presents several design configurations of rectangular microstrip patch antenna (RMSA) arrays that function at the S-band frequency point. Through the utilization of high-frequency structure simulator (HFSS) and computer simulation technology (CST) software, it is possible to get the antenna gain, VSWR, return loss, and bandwidth, as demonstrated by the results of each simulation. The results obtained are in good agreement with those previously explored for the same array types that operate at S-band frequencies. Additionally, there is an advancement in the results that were obtained.

There has been a tremendous increase in microstrip antennas, which are currently widely used in various cutting-edge microwave systems. The rapid proliferation of refined and improved applications encouraged ongoing research intending to fine-tune and enhance the fundamental features of the technology [20]. Modifying the designer's choices of substrate type, antenna structure, perturbation type, and feeding method can achieve the antenna design goal. Wireless communication systems require certain conditions to be met to transfer massive amounts of data in real time.

3. MATERIAL AND METHOD

Microstrip patch antennas are antennas that have a low-profile dimension and it utilized in applications that have a low profile and operate at frequencies greater than 100 MHz. A metal patch mounted at ground level and dielectric materials sandwiched between them form a microstrip. Conductive materials: Conductive materials, such as copper or gold, construct the patch on the upper surface. It is possible for the geometric shape of the conductor that will be employed to change depending on the architectural characteristics [21]. The first thing to be done to build a microstrip patch antenna (MPA) is to describe its essential characteristics. These parameters include the operating frequency and the material specifications that will be used for the substrate. These specifications include the material's relative permittivity, thickness, and tangential loss [22]. Regarding the operation of MPA, substrate selection is essential. These features, which are presented in Table 1, describe the substrate that was chosen for this particular piece of research. Figure 2 shows the flow chart of the proposed antenna design.

Table 1. Distinguishing features of the substrate material

Type of substrate	FR-4 (lossy)
Dielectric permittivity (ε)	4.3
Thickness (h_s)	1.65 mm
Loss tangent	0.025

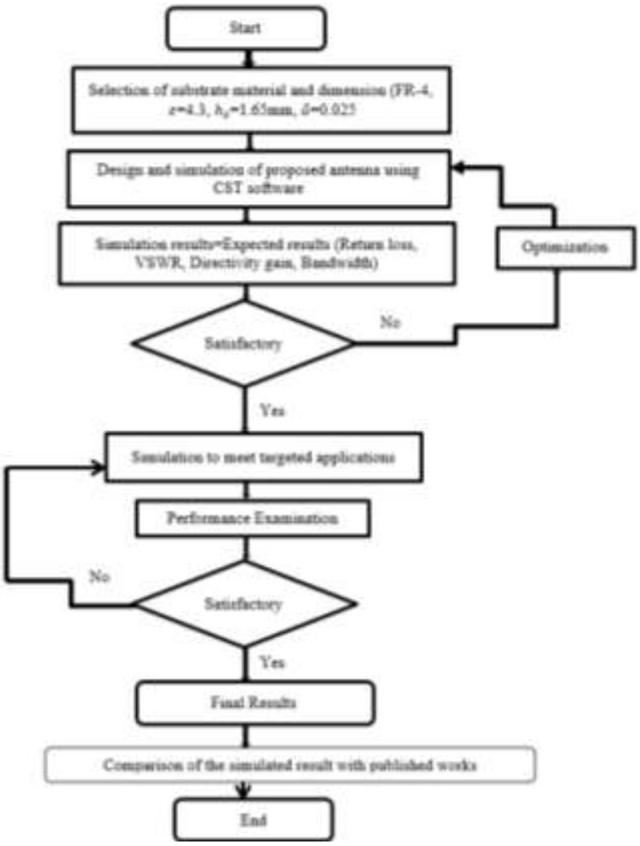

Figure 2. Schematic flow chart of the proposed antenna

The second stage involves using the equations to choose the shape of the patch, the type of conductor it will have, and the size it will have. Among the various forms of patches described in the literature, the rectangle shape, which is a perfect conductor, will be discussed in detail throughout this work. According to (1) and (5), the objective is to ascertain the dimensions of the patch. In the following, you will find these equations: The width of the patch is denoted by W_P, and length L_P. The dielectric effective permittivity is characterised by ε_{reff}. The thickness of the substrate is characterized by h. The wavelength is determined by λ. The resonance frequency is determined by f_r. The speed of light in a vacuum is denoted by C.

This proposed microstrip patch antenna has three important design parameters. The height of the dielectric substrate (h_S), the relative dielectric constant of the substrate (ε_r), and the frequency of operation (f_o) are the different parameters that are being discussed here. It has been decided that the antenna will have a resonance frequency of 3.5 GHz. FR-4 was picked as the dielectric material for this project because it has a loss tangent of 0.025 and a relative dielectric constant of 4.3. It has been decided that the height of the dielectric substrate would be 1.65 mm, which is one of the standard substrate thicknesses accessible in the industry. A transmission line model was utilized to compute the parameters for a rectangular microstrip patch antenna operating in the S-band. Considering the outcome, the length of the patch is 20 mm, the width is 26 mm. Using the dielectric constant 4.3, a substrate with a ground plane length (L_g) of 40.5 mm and a ground plane width (Wg) of 39.1 mm was made for an antenna that works at 3.5 GHz. This substrate was obtained for the antenna. To obtain the values of the parameters for this inquiry, the equations displayed lower down the page are utilized. It is measured across the patch antenna's width in the microstrip format. This line of investigation uses the (1) to (7) to ascertain the correct values that should be provided to the parameters to compute them [16], [23].

Step 1: the width of the patch.

$$\mathrm{Wp} = \frac{c_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

Step 2: calculating the effective dielectric constant of the substrate is one of the most critical steps in designing an antenna.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12 \times \frac{h}{\mathrm{Wp}}\right)^{-\frac{1}{2}} \tag{2}$$

Step 3.

$$L_{eff} = \frac{c_o}{2f_r\sqrt{\varepsilon_{reff}}} \tag{3}$$

Step 4: computing the length extension of an antenna.

$$\Delta L = 0.412h \frac{\left(\frac{\mathrm{Wp}}{h} + 0.3\right)(\varepsilon_{reff} + 0.264)}{(\varepsilon_{reff} - 0.258)\left(\frac{\mathrm{Wp}}{h} + 0.8\right)} \tag{4}$$

Step 5: the computation of the antenna's length is a fundamental calculation in antenna design.

$$L_P = L_{eff} - 2\Delta L \tag{5}$$

Step 6: after that, the dimensions of the rectangular microstrip patch, as well as the length and width of the ground plane, may be calculated in (6) and (7).

$$\mathrm{Lg} = 6h + L_P \tag{6}$$

$$\mathrm{Wg} = 6h + \mathrm{Wp} \tag{7}$$

4. PROPOSED ANTENNA DESIGN AND SIMULATION RESULTS

The rectangular microstrip patch antenna (RMPA) shown in Figure 3 was constructed with the help of the CST software. Different kinds of software, such as HFSS, matrix laboratory (MATLAB), Feldberechnung für Körper mit beliebiger Oberfläche (FEKO), and so on, are utilized in the process of designing antennas; nevertheless, CST software is the kind of program that can be employed most straightforwardly and effectively. Return loss, VSWR, directivity gain, bandwidth, and surface current are just a few of the things the simulation for the planned antenna showed. The microstrip antennas are meant to work on the "Rogers RT5880" low-loss substrate at 3.5 GHz frequencies. The substrate has a loss tangent of 0.025 and a diectric constant of 4.3. The dimensions and geometry of the suggested antennas are displayed in

Figure 3, also Figure 4 shows the physical construction of antenna [24]. In this article, we present the design of a microstrip antenna for use in wireless systems operating in the 3.5 GHz band. The antenna significantly increases the directivity gain bandwidth while keeping the standard VSWR, whose ideal value is 1. The decision to choose a frequency of 3.5 GHz was made to validate the technique used in the design of the antennas for use at these frequencies, which are in great demand for wireless applications. The solution that reduces size utilizes a single patch element incorporated into each antenna's design.

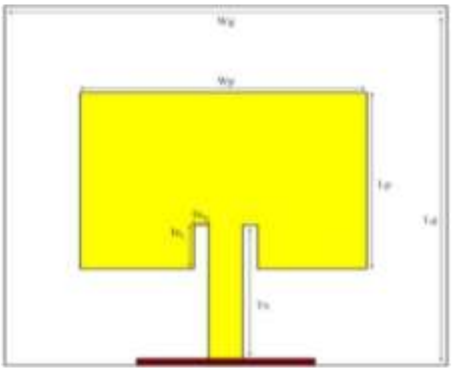

Figure 3. Shows the proposed antenna design using CST software

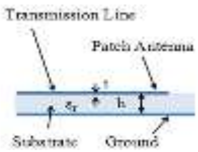

Figure 4. Physical construction of antenna [24]

4.1. Antenna parameter

To make a microstrip patch antenna that is structurally sound and good for communication, choose the right dielectric permittivity, resonating frequency, and substrate thickness (h). The many parameters of the designed antenna are presented in Table 2. The length and width of the antenna patch and the ground are both considered criteria. In addition, the height, the loss tangent, the width of the transmission line, and the inset's length and width are all discussed components.

Table 2. Geometry measurements for the proposed antenna

Parameter	W_g	L_g	W_p	L_p	H_s	t	I_L	I_W	Tx
Dimension (mm)	39.1	40.5	26	20	1.65	0.0025	4.8	1.5	3.313

4.2. Return loss (S_{11})

The reflection coefficient is often referred to as the return loss and is represented by the symbolS_{11}. This coefficient describes the amount of power reflected from the antenna and specifies the input-output relationship between the ports. The return loss map can extract the information required to achieve an optimal level of matching between the feedline and the antenna. When theS_{11} value is 0 dB, the antenna reflects all the power, and none is emitted. This is the case when there is no power being emitted. A value of at least -10 dB for the S_{11} parameter is required for the performance of an antenna to be considered compelling [25]. This antenna has a peak S-parameter of -56.82 dB at 3.5 GHz, translating to a value of -10 dB. The antenna's bandwidth is 0.148 GHz and tuned to the necessary operating frequency. As shown in Figure 5, the antenna has a S_{11} value of roughly -56.82 dB at its lowest point, which occurs at a frequency of 3.5 GHz. The value of return loss shifts whenever there is a change in either the ground length or the inset length of the antenna, as demonstrated in Table 3. Impedance matching of the antenna is better when the return loss value is lower. Figure 6 presents many return loss values calculated at 3.5 GHz, with the best value being -56.82.

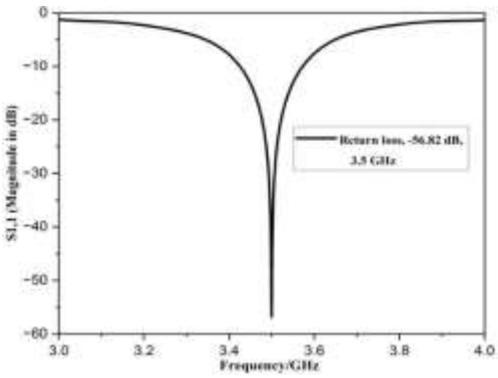

Figure 5. Showing graph of return loss vs frequency is presented for a single value

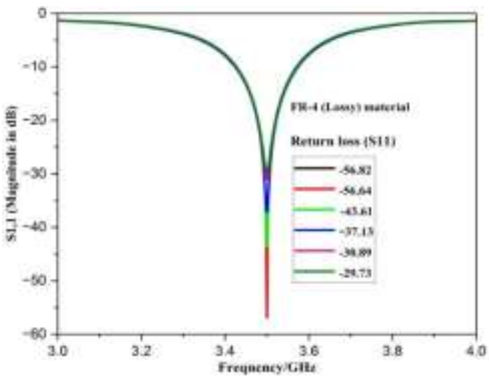

Figure 6. A graph of return loss vs frequency is presented for various values

Table 3. Shows the different values of return loss and VSWR with the changes of antenna length of groud and length of inset

Operating frequency	Length of the ground (L_g)	Inset length	Return loss (S_{11})	VSWR
3.5 GHz	40.5	4.8	-56.82	1.0028
	40.5	4.81	-56.64	1.0029
	40.5	4.85	-43.61	1.0132
	40.5	4.7	-37.13	1.0282
	40.5	5	-30.89	1.0587
	40.1	5	-29.73	1.0674

4.3. Voltage standing wave ratio

A voltage standing wave ratio, or VSWR, is the ratio of the highest peak voltage to the lowest peak voltage in a standing wave pattern where there is a change in impedance [3]. The reflection coefficient is a function that determines VSWR. The VSWR, also known as VSWR, is a measurement that indicates either the amount of power reflected from the antenna or the degree to which the impedance of the antenna matches that of the transmission line. For an antenna match to be regarded as very excellent, the VSWR value must fall between 1 and 2. If the value of the VSWR is smaller, then the outcome is better; this implies that the antenna and the transmission line are appropriately suited to one another and that more power is being transmitted to the antenna [26]. The Figures 7 and 8 demonstrates that the value of the VSWR of the antennas at the frequency of 3.5 GHz is exceptionally close to the value of 1. The value of VSWR is plotted versus frequency in Figure 7, which reveals that the value of 1.0028 is reached at 3.5 GHz. The value of VSWR changes with the antenna ground length and inset length change, which is discussed earlier in Table 3. Its values are varied until the VSWR value approaches 1. Figure 8 shows some VSWR values at 3.5 GHz, with the best value being 1.0028.

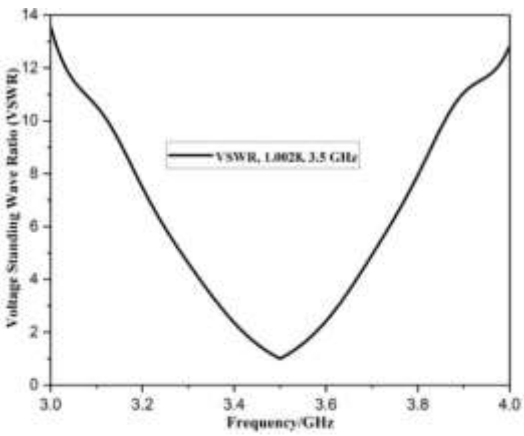

Figure 7. Showing graph of VSWR vs frequency is presented for a single value

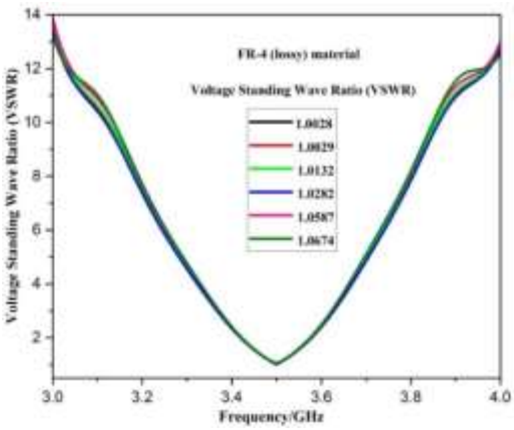

Figure 8. A graph of VSWR vs frequency is presented for various values

4.4. Gain and radiation pattern

The gain and directional performance of an antenna are directly related to one another [27]. The term "directivity" refers to the highest benefit that can be achieved in a given direction [3]. As a result, the antenna has a diversity gain of 6.02 dBi at 3.5 GHz, as demonstrated in Figure 9, which illustrates its radiation patterns in three dimensions. A three-dimensional representation of the radiation patterns is also shown in this graphic. Several different perspectives of the antenna's polar far-field pattern and the size of the primary beam, which is 6.02 dBi, are presented in this picture, referred to as Figure 10. In addition, it uncovers that the primary lobe of the antenna is oriented in the direction of -12.7 degrees, has an angular diameter of 97.3 degrees, and is pointed in the direction of 3 degrees.

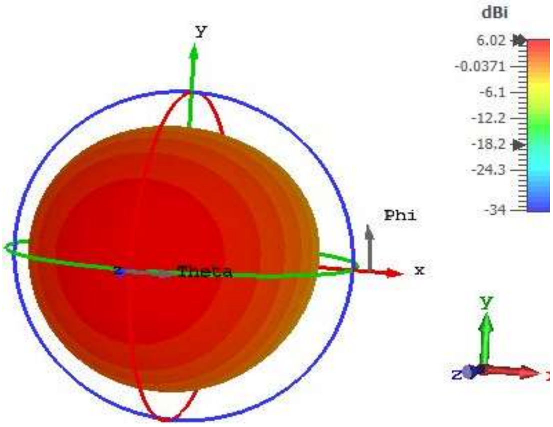

Figure 9. Shows the planned antenna's three-dimensional radiation pattern

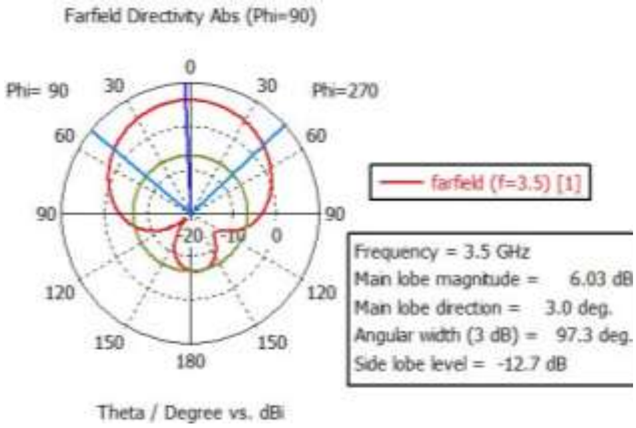

Figure 10. Shows the farfield directivity of the antenna that is being suggested

5. RESULT ANALYSIS

This section discussed the proposed antenna results, research gaps, and novelty. The designed and simulated antennas had better results than those in previous papers regarding bandwidth, return loss, VSWR, and directivity gain. These were -56.82 dBi for bandwidth, 1.0028 dBi for return loss, 6.02 dBi for directivity gain, and 148 MHz for VSWR. These results are better than those in previous papers. Comparison with previous published work shows that the proposed antenna suits wireless LAN applications. Finally, the performance of the suggested antenna is compared to other results published in the literature, and the results are presented in Tables 4 and 5. As a result of this comparison, a considerable improvement in the antenna gain is discovered, along with an acceptable size reduction.

Table 4. Comparison of the simulated result with published works

Ref.	Operating frequency	Substrate materials	Return loss (dB)	VSWR	BW (GHz)
[13]	3.5 GHz	Rogers RT5880	-14.02	-	0.050
[18]	3.5 GHz		-26.5	-	0.019
[28]	3.5 GHz	Fr-4	-41.31	1.017	-
			-43.95	1.013	-
			-20.44	1.21	-
[29]	3.5 GHz	Fr-4	-42.76	-	0.100
[30]	3.5 GHz	Rogers RT5880	-13.77	1.515	0.0236
[31]	3.5 GHz	Fr-4	-30.611	1.060	0.1441
[32]	3.5 GHz	Rogers RT5880	-50.422	1.0061	0.1221
[33]	3.6 GHz	Rogers RT5880	-17.626	1.3026	0.200
[34]	3.5 GHz	Rogers RT5880	-28.29	1.0801	0.111
[35]	3.29 GHz	Rogers RT5880	-33.69	1.04	-
[36]	3.36 GHz	-	−16.09	1.37	0.100
[37]	3.5 GHz	Rogers RT5880	-40.2827	1.02	0.200
[38]	3.45 GHz		below -10	-	0.140
[39]	3.32 GHz	Rogers 4003	-33	≤ 2	0.180
This work	3.5 GHz	Fr-4	-56.82	1.0028	0.148

Table 5. Comparison of simulated results to published works

Parameter	Operating frequency	Directivity gain (dBi)
[9]	3.5 GHz	1.88
[11]	3.5 GHz	5.3
[16]	3.6 GHz	2.52
[18]	3.5 GHz	4.2
[28]	3.5 GHz	4.57
		4.90
		5
[31]	3.5 GHz	6.05
[34]	3.5 GHz	5.43
[35]	3.29 GHz	3.38
[36]	3.36 GHz	1.07
[37]	3.5 GHz	5.8
[38]	3.45 GHz	3.83
[40]	3.5 GHz	4.28
[41]	3.45 GHz	4.64
[42]	3.5 GHz	3.338
		4.66
		5.08
This work	3.5 GHz	6.02

6. CONCLUSION

A 3.5 GHz microstrip patch antenna has been designed in the said paper. The designed antenna had a return loss of -56.82 dBi, a VSWR of 1.0028, a directivity gains of 6.02 dBi, and a bandwidth of 0.148 GHz. These results can be used in wireless applications. The paper's novelty is to increase the return loss to bring the VSWR closer to 1 and increase the directivity gain of the antenna, which is better than the results of previously published work. As this return loss increases, the antenna impedance matching improves. And this proposed antenna may be a good candidate for future wireless LAN applications. Besides, the proposed antenna can be fabricated and compared with the simulated results. To design and improve the performance of a wide variety of microstrip antennas that will be utilized in wireless communication systems, the combination of these a technology has the potential to be applied in the work that will be carried out in the future. This work will be carried out in the future.

REFERENCES

[1] G. Varamini, A. Keshtkar, and M. Naser-Moghadasi, "Miniaturization of microstrip loop antenna for wireless applications based on metamaterial metasurface," *AEU - International Journal of Electronics and Communications*, vol. 83, pp. 32–39, Jan. 2018, doi: 10.1016/j.aeue.2017.08.024.

[2] R. K. Verma and D. K. Srivastava, "Bandwidth improvement of stub loaded compact ultra-wideband microstrip patch antenna for C/X-band applications," *Wireless Personal Communications*, vol. 120, no. 1, pp. 185–202, 2021, doi: 10.1007/s11277-021-08441-z.

[3] P. Elechi and C. P. Obi-Ijeoma, "Performance analysis of an ultra-wide band (UWB) antenna for communication system," *Trends Journal of Sciences Research*, vol. 2, no. 1, pp. 1–12, Aug. 2022, doi: 10.31586/ojes.2022.359.

[4] M. A. Al-Mamun, S. Datto, and M. S. Rahman, "Performance analysis of rectangular, circular and elliptical shape microstrip patch antenna using coaxial probe feed," in *2017 2nd International Conference on Electrical & Electronic Engineering (ICEEE)*, Dec. 2017, pp. 1–4, doi: 10.1109/CEEE.2017.8412912.

[5] M. S. Rana, B. K. Sen, M. T. Al Mamun, M. S. Mahmud, and M. M. Rahman, "A 2.45 GHz microstrip patch antenna design, simulation, and anlaysis for wireless applications," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 4, pp. 2173–2184, Aug. 2023, doi: 10.11591/eei.v12i4.4770.

[6] P. M. Ridoy, K. M. Elme, R. Shihab, P. Saha, M. J. Al-Mursalin, and N. Alam, "A simple design of microstrip patch antenna for WLAN application using 5.4 GHz band," in *Lecture Notes in Electrical Engineering*, vol. 878 LNEE, 2022, pp. 574–581.

[7] S. R. M. González and R. T. R. Márquez, "Computational simulation applied to 3.5 GHz band microstrip yagi array antenna design for 5G technology mobile wireless device," in *Communications in Computer and Information Science*, vol. 1906 CCIS, 2023, pp. 312–322.

[8] W. An, Y. Li, H. Fu, J. Ma, W. Chen, and B. Feng, "Low-profile and wideband microstrip antenna with stable gain for 5G wireless applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 4, pp. 621–624, Apr. 2018, doi: 10.1109/LAWP.2018.2806369.

[9] F. Faisal, Y. Amin, Y. Cho, and H. Yoo, "Compact and flexible novel wideband flower-shaped CPW-fed antennas for high data wireless applications," *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 6, pp. 4184–4188, Jun. 2019, doi: 10.1109/TAP.2019.2911195.

[10] N. Ferdous, G. C. Hock, H. A. S. Hamid, M. N. A. Raman, T. S. Kiong, and M. Ismail, "Design of a small patch antenna at 3.5 GHz for 5G application," *IOP Conference Series: Earth and Environmental Science*, vol. 268, no. 1, p. 012152, Jun. 2019, doi: 10.1088/1755-1315/268/1/012152.

[11] F. Cirik and B. S. Yildirim, "Analysis and design of a 3.5-GHz patch antenna for WiMAX applications," *International Journal of Microwave and Wireless Technologies*, vol. 8, no. 1, pp. 63–70, Feb. 2016, doi: 10.1017/S1759078714001238.

[12] A. J. A. Al-Gburi, Z. Zakaria, I. M. Ibrahim, and E. B. A. Halim, "Microstrip patch antenna arrays design for 5G wireless backhaul application at 3.5 GHz," in *Lecture Notes in Electrical Engineering*, vol. 865, 2022, pp. 77–88.

[13] M. A. Azeman, N. A. Malek, S. Y. Mohammad, and M. I. M. Ghazali, “Design of enhanced gain patch antenna at 2.4 GHz and 3.5 GHz for wireless application,” *Journal of Physics: Conference Series*, vol. 2250, no. 1, p. 012012, Apr. 2022, doi: 10.1088/1742-6596/2250/1/012012.

[14] S. K. Ezzulddin, S. O. Hasan, and M. M. Ameen, “Microstrip patch antenna design, simulation and fabrication for 5G applications,” *Simulation Modelling Practice and Theory*, vol. 116, p. 102497, Apr. 2022, doi: 10.1016/j.simpat.2022.102497.

[15] K. R. Prabha, B. Nataraj, and M. Jagadeeswari, “Design and analysis of microstrip patch antenna for sub-6GHz applications,” in *2022 1st International Conference on Electrical, Electronics, Information and Communication Technologies, ICEEICT 2022*, Feb. 2022, pp. 1–3, doi: 10.1109/ICEEICT53079.2022.9768490.

[16] A. A. Abdulbari *et al.*, “Design compact microstrap patch antenna with t-shaped 5G application,” *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 10, no. 4, pp. 2072–2078, Aug. 2021, doi: 10.11591/EEI.V10I4.2935.

[17] G. V. Raviteja, “Design and analysis of a novel dual trapezoidal slot-based rectangular microstrip antenna for wide area network using WiMax application,” *Microwave and Optical Technology Letters*, vol. 60, no. 4, pp. 1057–1060, Apr. 2018, doi: 10.1002/mop.31100.

[18] M. Z. B. Chowdhury, M. T. Islam, H. Rmili, I. Hossain, M. Z. Mahmud, and M. Samsuzzaman, “A low-profile rectangular slot antenna for sub-6 GHz 5G wireless applications,” *International Journal of Communication Systems*, vol. 35, no. 17, Nov. 2022, doi: 10.1002/dac.5321.

[19] S. O. Hasan, S. K. Ezzulddin, R. H. Mahmud, and M. J. Ahmed, “Design and simulation of microstrip antenna array operating at s-band for wireless communication system,” *International Journal of Electrical and Computer Engineering Systems (IJEECS)*, vol. 14, no. 5, pp. 497–506, Jun. 2023, doi: 10.32985/ijeces.14.5.1.

[20] M. M. H. Mahfuz and C. W. Park, “Review of patch antennas used in drone applications,” *IEEE Access*, vol. 11, pp. 58367–58388, 2023, doi: 10.1109/ACCESS.2023.3284040.

[21] A. N. A. M. Karahan, M. Inal, A. Dilmen, F. Lacinkaya, and C. Kasnakoglu, “Microstrip patch antenna design at 10 GHz for X band applications,” *arXiv (Cornell University).*, 2023.

[22] W. En-Naghma, H. Halaq, and A. El Ougli, “Novel broadband circularly polarized pentagonal printed antenna design for wireless power transmission applications,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 32, no. 3, pp. 1434–1441, Dec. 2023, doi: 10.11591/IJEECS.V32.I3.PP1434-1441.

[23] R. P. T. T. S. Borel, “A microstrip patch antenna designed for 25 GHz applications,” *International Journal of Research and Analytical Reviews (IJRAR)*, vol. 10, no. 1, pp. 134–139, 2023.

[24] M. S. Rabbani and H. Ghafouri-Shiraz, “Improvement of microstrip patch antenna gain and bandwidth at 60 GHz and X bands for wireless applications,” *IET Microwaves, Antennas and Propagation*, vol. 10, no. 11, pp. 1167–1173, Aug. 2016, doi: 10.1049/iet-map.2015.0672.

[25] M. Faisal, A. Gafur, S. Z. Rashid, M. O. Shawon, K. I. Hasan, and M. B. Billah, “Return loss and gain improvement for 5G wireless communication based on single band microstrip square patch antenna,” in *1st International Conference on Advances in Science, Engineering and Robotics Technology 2019, ICASERT 2019*, May 2019, pp. 1–5, doi: 10.1109/ICASERT.2019.8934474.

[26] K. Chang, *RF and Microwave Wireless Systems*. John Wiley & Sons, 2004.

[27] M. I. Hossain, M. A. Islam, M. T. Ahmed, and M. H. Kabir, “Design of a high-gain 2 & 1 array antenna for s-band applications,” *World Journal of Engineering and Technology*, vol. 11, no. 02, pp. 293–302, 2023, doi: 10.4236/wjet.2023.112021.

[28] M. M. Hasan, Z. Rahman, R. Shaikh, I. Alam, M. A. Islam, and M. S. Alam, “Design and analysis of elliptical microstrip patch antenna at 3.5 GHz for 5G applications,” in *2020 IEEE Region 10 Symposium, TENSYMP 2020*, 2020, pp. 981–984, doi: 10.1109/TENSYMP50017.2020.9230897.

[29] S. K. Noor *et al.*, “Generation of OAM waves and analysis of mode purity for 5G sub-6 GHz applications,” *Computers, Materials and Continua*, vol. 74, no. 1, pp. 2239–2259, 2023, doi: 10.32604/cmc.2023.031170.

[30] M. S. Rana, S. I. Islam, S. Al Mamun, L. K. Mondal, M. T. Ahmed, and M. M. Rahman, “An s-band microstrip patch antenna design and simulation for wireless communication systems,” *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)*, vol. 10, no. 4, pp. 945–954, Dec. 2022, doi: 10.52549/ijeei.v10i4.4141.

[31] S. Rana, N. Khurshid, S. K. Joy, S. I. Sourav, J. Hassan, and J. Nazmul, “A 3.5 GHz microstrip patch antenna design and analysis for wireless applications,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 32, no. 2, pp. 828–837, Nov. 2023, doi: 10.11591/ijeecs.v32.i2.pp828-837.

[32] M. S. Rana, T. A. Fahim, B. Ghosh, and M. M. Rahman, “Microstrip patch antenna design and simulation for S-band wireless applications operating at 3.5 GHz,” *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 12, no. 6, pp. 3428–3437, Dec. 2023, doi: 10.11591/eei.v12i6.5626.

[33] M. S. Rana, T. A. Fahim, S. B. Rana, R. Mahbub, and M. M. Rahman, “Design, simulation, and analysis of microstrip patch antenna for wireless applications operating at 3.6 GHz,” *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 21, no. 5, pp. 957–967, Oct. 2023, doi: 10.12928/TELKOMNIKA.v21i5.24813.

[34] M. S. Rana, S. K. S. Shuva, S. Ahmed, M. H. O. Rasid, S. Md. R. Islam, and M. M. Rahman, “Design, simulation and analysis of 3.5 GHz microstrip patch antenna for wireless communication systems,” in *2023 14th International Conference on Computing Communication and Networking Technologies, ICCCNT 2023*, Jul. 2023, pp. 1–7, doi: 10.1109/ICCCNT56998.2023.10307552.

[35] L. C. Paul, H. K. Saha, T. Rani, M. Z. Mahmud, T. K. Roy, and W. S. Lee, “An omni-directional wideband patch antenna with parasitic elements for sub-6 GHz band applications,” *International Journal of Antennas and Propagation*, vol. 2022, pp. 1–11, Oct. 2022, doi: 10.1155/2022/9645280.

[36] A. B. Sahoo, N. Singh, and B. B. Mangaraj, “Design of an Arc-shaped slot circular patch antenna for 5G applications,” in *2023 1st International Conference on Circuits, Power, and Intelligent Systems, CCPIS 2023*, Sep. 2023, pp. 1–4, doi: 10.1109/CCPIS59145.2023.10291475.

[37] A. B. Sahoo, N. Patnaik, A. Ravi, S. Behera, and B. B. Mangaraj, “Design of a miniaturized circular microstrip patch antenna for 5G applications,” in *International Conference on Emerging Trends in Information Technology and Engineering, ic-ETITE 2020*, Feb. 2020, pp. 1–4, doi: 10.1109/ic-ETITE47903.2020.374.

[38] S. K. Noor *et al.*, “A patch antenna with enhanced gain and bandwidth for sub-6 GHz and sub-7 GHz 5G wireless applications,” *Electronics (Switzerland)*, vol. 12, no. 12, p. 2555, Jun. 2023, doi: 10.3390/electronics12122555.

[39] A. S. A. Halim, M. Mostafa, and O. Hamdy, "Design and implementation of 3.2-GHz co-planar miniaturized antenna for s-band communication and wireless applications," *Wireless Personal Communications*, vol. 132, no. 3, pp. 1887–1897, Oct. 2023, doi: 10.1007/s11277-023-10686-9.

[40] C. Pochaiya, S. Chandhaket, P. Leekul, J. Mearnchu, T. Tantisopharak, and T. Limpiti, "Bandwidth enhancement of dual-band bi-directional microstrip antenna using complementary split ring resonator with defected structure for 3/5 GHz applications," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 2, pp. 1683–1694, Apr. 2022, doi: 10.11591/ijece.v12i2.pp1683-1694.

[41] Y. Benghanem, A. Mansoul, and L. Mouffok, "Frequency reconfigurable two-element MIMO antenna for cognitive radio and 5G new radio sub-6 GHz applications," *International Journal of Microwave and Wireless Technologies*, pp. 1–11, Nov. 2023, doi: 10.1017/S1759078723001289.

[42] N. Ramli, S. K. Noor, T. Khalifa, and N. H. A. Rahman, "Design and performance analysis of different dielectric substrate based microstrip patch antenna for 5G applications," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 8, pp. 77–83, 2020, doi: 10.14569/IJACSA.2020.0110811.

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