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A 3.5 GHZ MICROSTRIP PATCH ANTENNA DESIGN AND SIMULATION FOR S-BAND WIRELESS APPLICATIONS

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Abstract

In today's fast-changing information technology, there has been an uptick in demand for wireless applications, which has impacted antenna design. In wireless applications, there is a place for a wide variety of antenna types, including array antennas, microstrip patch antennas, wire antennas, aperture antennas, reflector antennas, and lens antennas. This research shows the simulation of an S-band microstrip patch antenna planned for future wireless applications. FR-4 (lossy) and Rogers RT5880 (lossy) were the two substrate materials modeled in these simulations. These materials have thicknesses of 2.94 millimeter, and their dielectric constants are 2.2 and 4.4, respectively—thicknesses of 0.077 millimeter. Using the CST software, different antenna designs were developed and independently compared. Within the frequency range of 3.5 GHz, the modeling results for the FR-4 substrate indicate the following parameters: return loss of -17.072 dB, VSWR of 1.3294, the bandwidth of 120.9 MHz, gain of 3.321 dBi, directivity of 7.57 dBi, and efficiency of 43.88%. At the same frequency, the findings for Rogers RT5880 substrates provide a return loss of -13.772 dB, a VSWR of 1.5152, a bandwidth of 23.4 MHz, a gain of 7.55 dBi, a directivity of 8.43 dBi, and an efficiency of 89.56%. This research aimed to reduce the return loss, increase gain directivity, and improve antenna efficiency, which plays a very important role in wireless applications (especially in WLANs and Mobile Phones).

Keywords: Microstrip Patch Antenna, Wireless Applications, VSWR, CST, FR-4, Rogers RT5880, WLANs

1. INTRODUCTION

Wireless communication has seen significant developments over the past few decades, substantially impacting antenna technology development. The result of wireless communication can be divided into four generations: the first generation in the 1980s, the second in the 1990s, the third in 2001, and the fourth in the 2010s. A distinct set of characteristics distinguishes each generation. Certain nations have set the year 2020 as their goal for the development of technology of the fifth generation, often known as 5G. This exemplifies the continuous development that is taking place, as well as the anticipation that surrounds the next step in wireless communication. [1]. Microstrip patch antennas are just one example of the many antennas that have found use alongside the various generations of wireless communication. The technology underpinning microstrip antennas entered a period of rapid development in the late 1970s, representing a critical turning point in the history of this field. By the early 1980s, microstrip antennas'

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fundamental parts and arrays had undergone thorough design and modeling, providing a solid foundation for their later use in various applications. This foundation was established because microstrip antennas have been used since the early 1960s. Microstrip patch antennas owe a significant amount of their current capabilities and potential to the advances made during this period [2].

Patch antennas are gaining popularity due to their widespread utilization across various electronic systems. These antennas find applications in diverse fields, such as electronic warfare, remote sensing, wireless communication, cell phones, space exploration, and more. The increasing popularity of patch antennas can be attributed to several factors, including their ease of installation, cost-effectiveness, compact size, and lightweight nature. These qualities make them highly versatile and suitable for various applications. As new communication technologies emerge and evolve, antenna design has to adapt and accommodate various requirements and specifications. This complexity arises from optimizing antenna performance, ensuring compatibility with different frequency bands, adhering to specific design constraints, and integrating advanced electronic systems [3]. Figure 1 depicts the physical structure of the microstrip patch antenna (MPA). The MPA design calls for using three layers of metal and substrate materials in its production. Copper or another high-quality conductor is generally used in the production of the foundational and grounding layers of a structure. A dielectric material, such as air, FR4, Roggers, or one of the many other acceptable alternatives, makes up the middle layer and the substrate layer. Copper or another highly conductive material is typically used as the primary component in constructing the patch or design layer, which is the very uppermost layer. The microstrip patch antenna can perform its functions effectively and efficiently thanks to this multilayer design [4]. The MPA can be a square, rectangular, square ring, circular, semicircular, elliptical, angular, or triangular, among other shapes [5]. As shown in figure 2[6], the rectangular microstrip patch antenna, also known as the MPA, can be created in various configurations. These designs include a rectangle 2(a), a square 2(b), a circular 2(c), a triangle 2(d), a donut 2(e), and a dipole 2(f). Microstrip antennas come in various forms, each serving specific purposes within a communication system.

In this article, we focus on designing and constructing a microstrip patch antenna with a rectangular shape, explicitly targeting a frequency range of 3.5 GHz. The research presented here explores a novel concept for an S-band antenna. To achieve the desired characteristics within the S-band frequency range at 3.5 GHz, a patch antenna with a square shape was employed as the basis for the design. The article delves into the details of this innovative approach, highlighting the rectangular microstrip patch antenna's unique aspects and performance attributes for S-band applications at the specified frequency.

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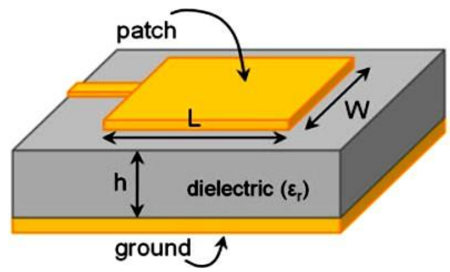

Figure 1: Physical construction of microstrip patch antenna (MPA)

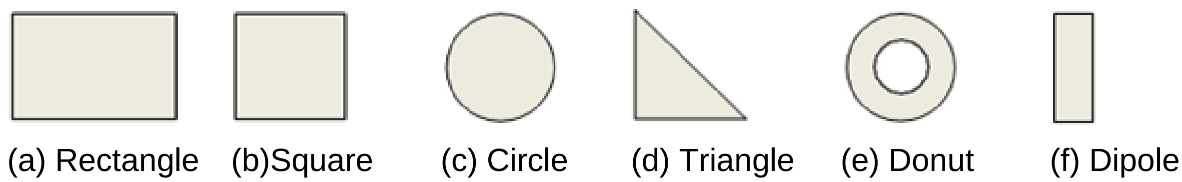

Figure 2: The representative shapes of microstrip patch elements are depicted as follows: (a) rectangle, (b)Square, (c) circle, (d) triangle, (e) donut, and (f) dipole

2. LITERATURE REVIEW

The Wireless communication is vital in the present era since it makes it possible to maintain continuous connections. Wireless technology simplifies our day-to-day activities because the internet and data transmission has become so fundamental to many facets of our lives. Despite operating within a restricted bandwidth and providing overall channel capacity, the arrival of 5G technologies offers significant advantages, including rapid data speeds. These advantages are available even though the technology operates within a limited bandwidth. The establishment of wireless links can be accomplished with the help of microstrip antennas, which are distinguished by their low profile and high gain. There is a significant amount of untapped potential inside the frequency range of 5G, which extends from 3 to 300 GHz. The lower frequency range that is a part of 5G has already found uses in various technologies such as Wi-Fi, WLAN, and Bluetooth, which further increase wireless communication in multiple scenarios [7]. Numerous scholars have conducted extensive research on microstrip patch antennas (MPAs) and shared their findings through research papers published in international journals and presented at conferences. The analysis of these research works provides valuable insights into the advancements and innovations in MPA technology. These studies cover various aspects of MPA design, analysis, and performance evaluation, including antenna geometry, materials, feeding techniques, radiation characteristics, bandwidth optimization, gain enhancement, and impedance matching. Additionally, research papers delve into the applications of MPAs in different fields, such as wireless communication systems, satellite communication, radar systems, and IoT devices. The pooled analysis of these scholarly contributions contributes to a deeper understanding of MPA technology and its potential impact on wireless communication.

Research by S. Hossain *et al.* [8], presents an innovative rectangular patch antenna design specifically tailored for S-band applications operating at a frequency of 3.5 GHz. The antenna's performance at this frequency exhibits notable improvements, including

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reduced return loss, increased bandwidth, and enhanced gain. To achieve a wider bandwidth, the substrate thickness has been increased. Through extensive simulations, critical performance parameters such as gain, radiation pattern, and return loss have been evaluated and analyzed. The proposed antenna is designed to operate within the S-band frequency range. This study successfully demonstrates the effectiveness of the rectangular patch antenna in optimizing performance for 3.5 GHz applications. The analysis of simulation results aids in comprehending the antenna's performance across various key parameters. In summary, the study focuses on the rectangular patch antenna's suitability for the S-band frequency range, showcasing its improved features at 3.5 GHz.

This research introduces [9], a unique slotted octagonal patch antenna explicitly designed for utilization in 5G communication networks, and this antenna features slots, setting it apart in construction and functionality. These slots contribute to its distinct performance characteristics and enable its operation across a diverse frequency range. The antenna's slotted octagonal shape offers advantages regarding radiation pattern, impedance matching, and bandwidth, making it well-suited for 5G applications. This research explores the innovative design and operational capabilities of the slotted octagonal patch antenna, highlighting its potential contributions to the advancement of 5G communication networks.

In this study[10], a microstrip patch antenna operating at a frequency of 2.4 GHz was constructed and examined as a potential technology for future wireless communication systems. The primary objectives of this study were to reduce the return loss, increase the gain, and minimize the antenna's voltage standing wave ratio (VSWR). These parameters play critical roles in determining the overall performance and efficiency of the antenna. The antenna's ability to transmit and receive signals at the desired frequency range can be significantly enhanced by optimizing these characteristics. The study aimed to achieve these improvements to pave the way for advanced wireless communication technologies in the future.

Rana, Md Sohel, et al. [11], shows how to make a microstrip patch antenna that works at 3.5 GHz and how to analyze it for future wireless communication. The software applications included in the CST Studio package simulate the proposed antenna arrangement. Through this line of research, the researchers hoped to reach the following goals: a lower return loss, a more significant gain, a lower VSWR, better directivity, and more efficient operation. This antenna was made to work in different wireless communication situations and has been tested in those situations. As a reference antenna, it is used in communication satellites, weather radar, wireless LANs, multimedia applications in mobile TV and satellite radio, optical communications at 1460 to 1530 nm, and other wireless fidelity applications.

Ibrahim and Jebur [12], introduces a slotted feed line for proximity-coupled feeding of a rectangular microstrip patch antenna designed explicitly for 5G wireless applications. This research focused on developing a lightweight rectangular microstrip patch antenna with high gain and low cross-polarization characteristics, utilizing ground structure techniques. The proposed antenna model operates within the sub-6GHz band, explicitly targeting a

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frequency of 3.5 GHz, with a narrow bandwidth of 210 MHz centered on this frequency. To enhance the antenna's performance and improve the antenna's bandwidth, gain, efficiency, and return loss characteristics. The findings of this study demonstrate the feasibility and potential of the slotted feed line approach in proximity-coupled feeding for rectangular microstrip patch antennas, particularly for 5G wireless applications.

Ferdous *et al*. [13], focuses on designing and constructing a low-profile patch antenna tailored explicitly for 5G communication systems. After careful consideration, the resonant frequency of 3.5 GHz, which aligns with 5G applications, was selected. The primary radiating patch of the antenna is elliptical, and it is fed using a mechanism known as "line feeding." Various parameters were evaluated in the study, including S-parameters, antenna gain, directivity, and efficiency, enabling comprehensive analysis and observation of these characteristics. Its optimized design parameters and performance characteristics make it well-suited for applications that require seamless access to 5G networks. This research contributes to advancing antenna technologies for enabling robust 5G communication systems.

Ibrahim *et al.* [14], comprehensively explores utilizing a rectangular patch antenna array for 5G applications. The antenna design was optimized to achieve good return loss and acceptable insertion loss characteristics at a frequency of 3500 MHz, which aligns with the requirements of the 5G spectrum. A comparative analysis revealed that the array structure outperformed the single-element design, showcasing improved performance metrics. The proposed antenna design was carefully compensated to operate effectively within a frequency range encompassing Band 78, ensuring compatibility and efficient utilization of this frequency band. The findings of this study demonstrate the viability and advantages of employing a rectangular patch antenna array in 5G applications. The research [15], presented in this paper contributes to the advancement of graphene-based microstrip patch antennas by providing insights into the design process. The results and findings pave the way for developing efficient and high-performance graphene-based microstrip patch antennas, demonstrating their potential for various wireless communication applications.

The mentioned paper presents a microstrip patch antenna (MPA) design operating in the S-band at 3.5 GHz, utilizing two different substrate materials: FR-4 (lossy) and Rogers RT5880. The antenna design was simulated using CST software, and the results indicate that the method employing the Rogers RT droid 5880 substrate material outperforms the one using the FR-4 substrate material. The antenna design with Rogers RT5880 exhibits improvements in various performance metrics, such as reduced return loss, increased gain, enhanced directivity, and improved efficiency. These findings suggest that the Rogers RT5880 substrate material is better suited for achieving optimal antenna performance in the S-band. Unlike the Ku and Ka bands, one notable advantage of operating in the S-band is its reduced susceptibility to fading caused by rain. This characteristic enhances the reliability and stability of wireless communication systems utilizing the S-band, making it a desirable choice for specific applications.

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3. MATERIALS AND METHODS

The research for this work commenced with an extensive analysis of relevant literature reviews about the application of microstrip patch antennas in wireless systems. To establish a clear research direction, the initial step involved identifying the key parameters that needed to be satisfied for the antenna design. Subsequently, the choice of substrate material was determined, with FR-4 (lossy) and Roggers RT 5880 being selected for this investigation. The third stage of the research involved calculating the dimensions of the antenna. This encompassed determining the patch size, the ground plane, the substrate's surface area, the feeding channel, and other relevant parameters necessary for the antenna design. By systematically following these steps, the research aimed to develop an effective technique for designing microstrip patch antennas tailored for 5G wireless applications. The selection of suitable materials and precise dimension calculations form a crucial foundation for achieving the desired performance and functionality of the antenna design.

Once the antenna size has been determined through calculations and initial dimensions have been acquired, the subsequent step in the antenna design process involves utilizing the CST Studio Suite 2019 software. This software enables the creation of the antenna model based on the calculated dimensions. After the antenna model has been constructed, its performance criteria are further evaluated. This includes assessing various aspects such as dimensions, materials, gain, efficiency, directivity, and impedance matching. Additionally, parameters VSWR and return loss are considered, which essential indicators of antenna performance are.

The antenna's efficiency in its employment in wireless applications has been researched and evaluated. The next step was to study the impacts of the substrate thickness, the selection of the substrate material, the position of the shorting pin, and the feeding line widths to achieve the highest possible total antenna efficiency. An investigation has been conducted to determine how effectively the microstrip patch antenna operates and how it can be implemented in settings and circumstances involving wireless communication. The suggested antenna is depicted in Figure 3 as a flow chart, which illustrates the step-by-step design processes.

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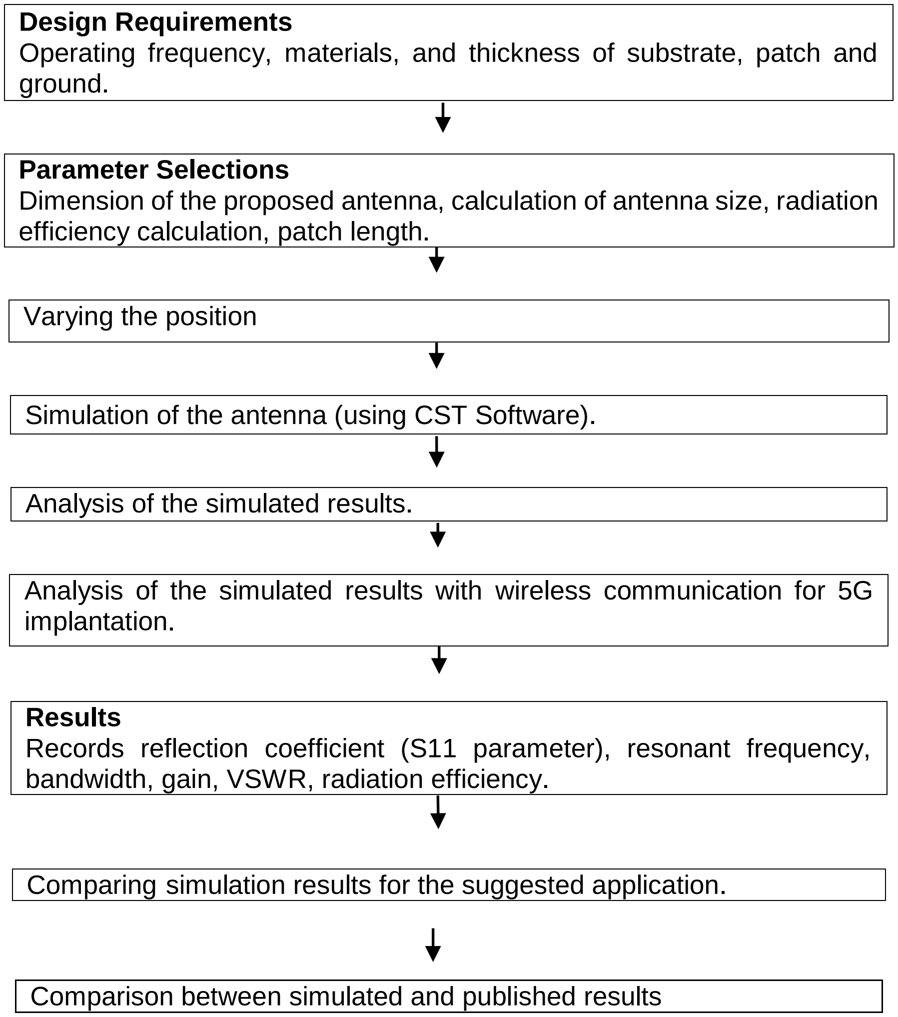

Figure 3: Diagrammatic Representation of the Planned Antenna

4. PROPOSED ANTENNA DESIGN AND SIMULATION RESTLTS

Figure 4 illustrates the results of simulating the MPA utilizing the CST software. To model the antenna design, the CST program provides various parameters. These parameters include return loss, VSWR, gain, directivity, radiation pattern, and efficiency—the performance of the suggested antenna design by researching and judging specific antenna parameters. The following section thoroughly reviews the simulated antenna designs for the MPA. We can analyze the suggested antenna design and investigate its performance with this information.

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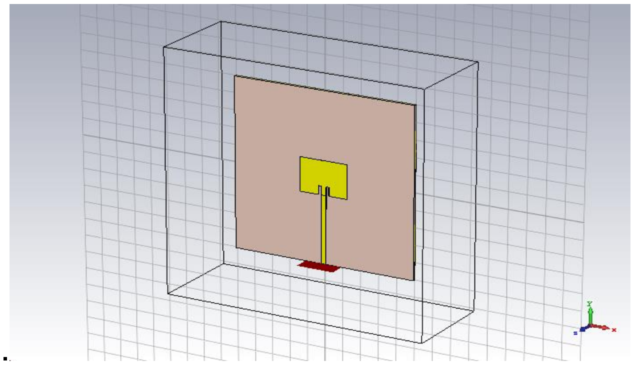

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Figure 4: The Configuration of the Antenna in the CST

This investigation makes use of the equations that are presented further down so that the values that should be assigned to the parameters can be found. When carrying out measurements using the microstrip format, the patch antenna's width must be considered. The research uses the set of equations provided below to determine the required values for the parameters that need to be used [16], [17].

Step: 01: The width of the patch for a rectangular microstrip antenna can be calculated using the formula:

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

In the equations provided, the symbol "c" stands for the velocity of light in a vacuum, which has been given a value of three times 3 x 10^8 meters per second. This number may be found in the previous sentence. $\varepsilon_r,$ Is the symbol used to represent the dielectric constant of the substrate, and "f" is the symbol used to indicate the frequency that is required for the antenna design. In addition, the symbol "Wp" indicates that the width of the antenna has been adjusted appropriately.

Step: 02: Determining the effective dielectric constant of the substrate is a crucial calculation in antenna design.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12 \times \frac{h}{\mathrm{Wp}}\right)^{-0.5} \tag{2}$$

Where, h is the height of the substrate and the effective dielectric constant isε_{reff}.

Step: 03: The calculation of the effective length of an antenna is an essential aspect of antenna design.

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

Step: 04: Computing the length extension of an antenna is a critical calculation in antenna design.

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

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

$$L = L\,eff - 2\Delta L \quad (5)$$

After that, the length and width of the ground plane, in addition to the rectangular microstrip patch, can be determined as

$$Lg=6h+L \quad (6)$$

$$Wg=6h+ Wp \quad (7)$$

4.1. Antenna Parameter

The outcomes of the measurements carried out on the antenna are presented in Table 1. The notation Wg denotes the ground's width and length, while the note Lg indicates its overall size. Hs denote the substrate's height, whereas the substrate's thickness is denoted by t. In addition, the width of the antenna patch is marked by the letter Wp, and the letter Lp indicates its length. It is essential to remember that the components themselves do not directly represent the components' values that go into making up the overall configuration but rather by other parameters.

FR-4 substrate		**Rogers RT5880**
Parameter	**Value (mm)**	**Value (mm)**
W_g	100	100
L_g	100	100
W_P	24.8	33
L_P	20	28.46
h_g	1.5	0.25
t	2.94	0.077
ε	2.2	4.4

4.2. Return Loss

The reflection coefficient, also known as return loss, is a crucial factor in assessing the performance of an antenna. A low return loss value, typically below -10 dB, indicates efficient communication and minimal signal reflections. The resonance frequency and bandwidth of the antenna are determined and measured through its S-parameters. Figure 5 illustrates the S-parameter characteristics for the proposed patch antennas using FR-4 and Rogers RT5880 substrate materials. The antennas operate at a resonance frequency of 3.5 GHz. The antenna's bandwidth using FR-4 substrate material is measured to be 3.4379-3.5588 GHz, while the return loss is -17.027 dB. On the other hand, the antenna utilizing Rogers RT5880 substrate material has a bandwidth of 3.4903-3.5139 GHz and a return loss of -13.772 dB. These measurements provide insights into the performance of the antenna design. The determined bandwidth indicates the frequencies over which

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the antenna can effectively operate. At the same time, the return loss values highlight the signal reflection and efficiency level at the resonance frequency of 3.5 GHz.

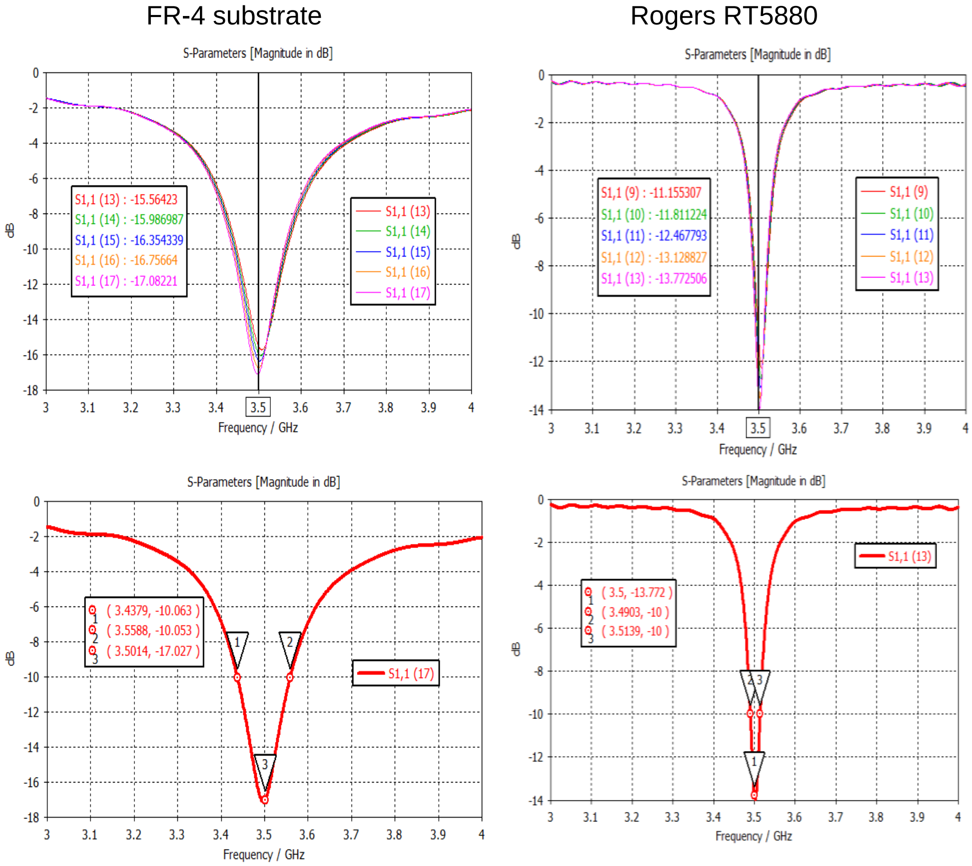

Figure 5: Graph showing frequency versus the amount of return loss

4.3. Vswr and Bandwidth

The Voltage Standing Wave Ratio (VSWR) is a measurement that indicates the efficiency of power transmission from a power source to a load through a transmission line. It is an essential parameter in assessing the performance of an antenna system. The ideal range for VSWR is typically between 1 and 2, with values closer to 1 indicating better impedance matching and more efficient power transfer[12]. Also, VSWR measurement provides valuable information about the transmission line's impedance characteristics and the antenna's ability to transfer power effectively. The antenna design ensures minimal signal reflection and optimal power transfer by achieving low VSWR values, contributing to reliable and efficient communication.

Figure 6 displays the computed values of VSWR for the antenna design at the frequency of 3.5 GHz. For the antenna constructed using FR-4 material, the VSWR is calculated to be 1.329, while for the antenna utilizing Rogers RT5880 material, the VSWR is 1.5152. These values fall within the desired range, indicating good impedance matching and efficient power transmission for both antenna designs.

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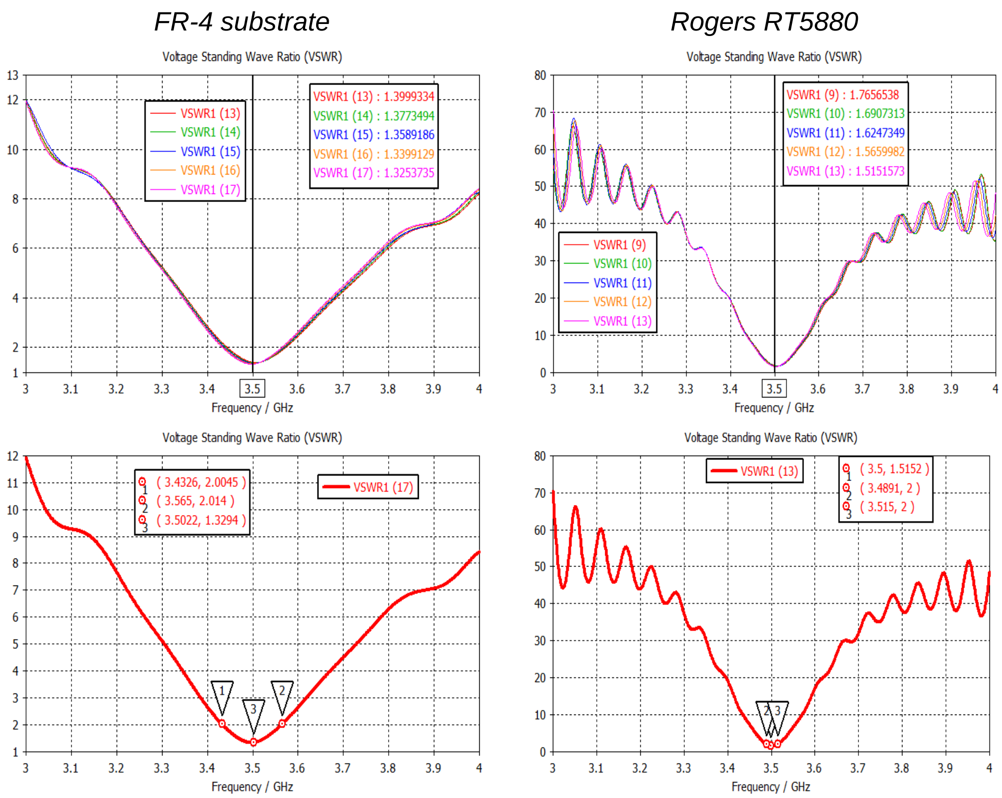

Figure 6: Create a Graph That Shows the Frequency versus the VSWR Result

4.4. Gain and Directivity

The term "gain" refers to the increase in power density of a directional antenna compared to that of an isotropic antenna (which radiates equally in all directions) when both antennas are fed with the same power. It indicates the antenna's ability to focus and direct the transmitted or received power in a particular direction[12]. Figure 7 displays the gain values for the rectangular patch antenna design using FR-4 and Rogers RT5880 substrate materials. The gain is measured at 3.321 dB for the FR-4 material and 7.55 dB for the Rogers RT5880 material at a frequency of 3.5 GHz. The proposed design achieves a gain of 7.55 dB, indicating its ability to efficiently concentrate the radiated power in a specific direction. Directivity, as shown in Figure 8, represents the ratio of the radiation intensity in a specific direction from an antenna to the average radiation intensity overall orders [12]. It provides insight into how focused the antenna's radiation pattern is. At a frequency of 3.5 GHz, with a phi angle of 90 degrees, the directivity is measured to be 7.57 dBi for FR-4 material and 8.44 dBi for Rogers RT5880 material. The proposed design achieves a directivity of 8.44 dBi, indicating its ability to effectively concentrate the radiated power in the desired direction. This improvement contributes to better signal strength and coverage in the intended order, making the antenna design suitable for its intended wireless communication application.

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FR-4 substrate *Rogers RT5880*

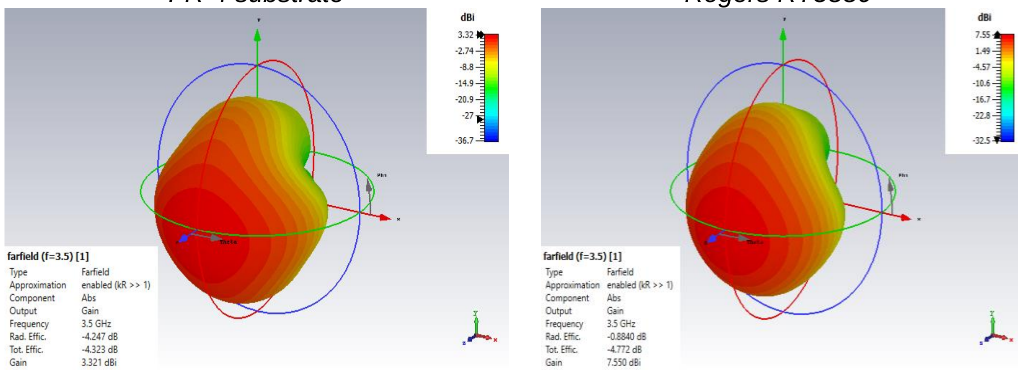

Figure 7: 3D Gain Field Configuration Of The MPA

FR-4 substrate Rogers RT5880

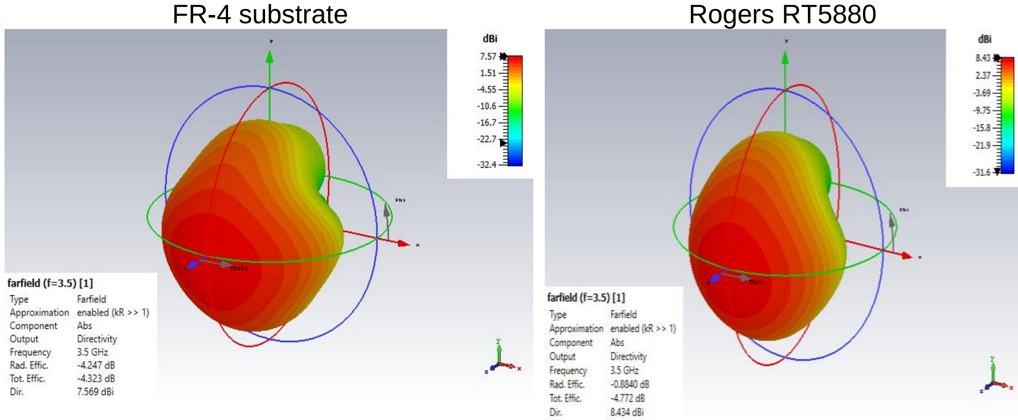

Figure 8: Demonstrates the Gain Pattern in Polar Form

Figure 9 is an illustration showing a representation of the polar radiation pattern. The central lobe of the radiation reflected off of FR-4 Substrate material has an intensity of 3.33 dB, and its angle of incidence is 3.0 degrees. The 3dB angle has a value of 85 degrees, and that value has been assigned to it. This antenna has a sidelobes level of -11.4 dB on the sidelobe scale. To reiterate, the magnitude of the center lobe is 7.56 dBi, and the angle is 3 degrees. This applies to the buried material used by Rogers RT5880. A figure of 72.5 degrees represents the 3dB angular value. Regarding this antenna's sidelobe level, the measurement comes in at -14.4 dB.

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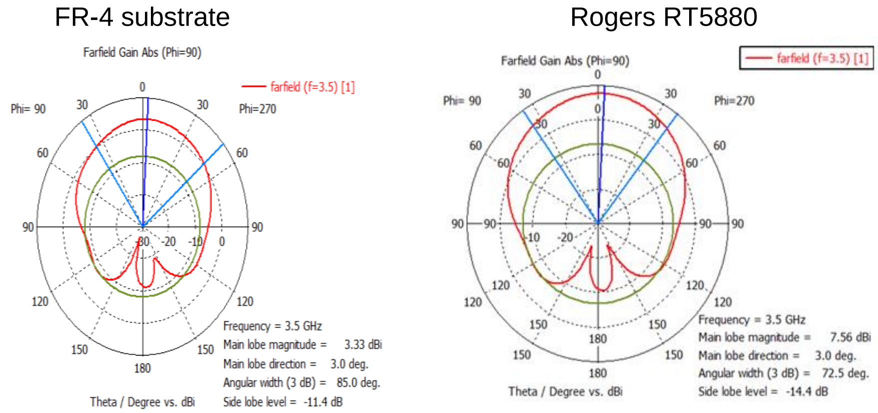

Figure 9: Proposed Antenna Farfield Gain

Figure 10 illustrates the polar directivity. The magnitude of the primary lobe is 7.57 dBi, and its angle of incidence is 3.0 degrees when considering FR-4 Substrate material. The 3dB angular value was calculated to be 85 degrees, as was previously mentioned. The intensity of sidelobes produced by this antenna is 11.4 dB lower than the average. In the case of the Roggers RT5880 material, the magnitude of the center lobe is 8.44 dBi, and the angle is 3 degrees. The angular value of 3 dB has been calculated to be 7.5 degrees, and the side lobe has been measured to be -14.4 dBi.

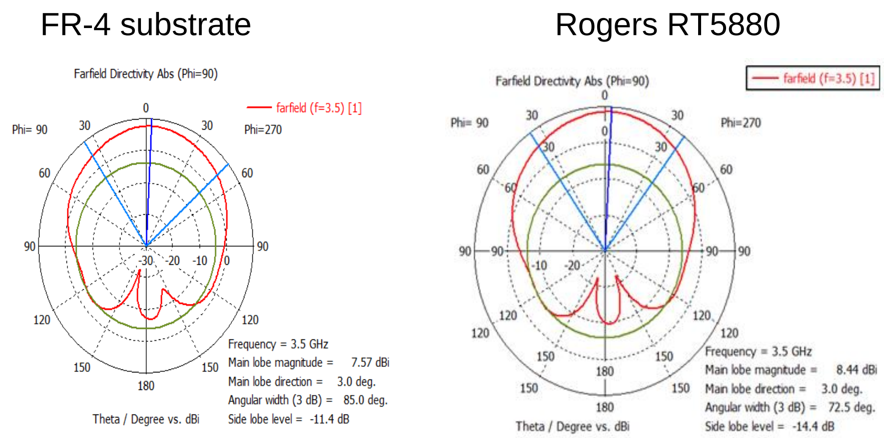

Figure 10: Proposed Antenna Farfield Directivity

4.5. RADIATION EFFICIENCY

The term "efficiency" refers to the amount of energy that needs to be put into an antenna for effective communication [18]. The power given to an antenna and the power that the antenna itself either emits or dissipates can be used as metrics to determine how effective the antenna is. Most of the power sent to an antenna with low efficiency is either lost due to losses within the antenna itself or is reflected away because of an impedance mismatch [19].

∴ Antenna efficiency = $\frac{\text{Gain}}{\text{Directivity}} \times 100\%$

In the case of FR-4 and Roggers RT5880, the respective radiation efficiencies are 43.88% and 89.56%. A radiation efficiency magnitude of 89.56% can be achieved with the suggested device when operating at a frequency of 3.5 GHz.

5. RESULTS ANALYSIS

In this study, simulations were conducted for wireless applications operating at a frequency of 3.5GHz, using two different substrate materials: FR-4 and Rogers RT5880. For the antenna design using FR-4 material, the simulation results indicate a return loss of -17.072 dB, gain of 3.321 dB, directivity of 7.57 dBi, bandwidth of 0.1209 GHz, VSWR of 1.3294, and efficiency of 43.88%.On the other hand, for the antenna design using Rogers RT5880 material, the simulation results show a return loss of -13.772 dB, gain of 7.55 dB, directivity of 8.43 dBi, bandwidth of 23 MHz, VSWR of 1.5152, and efficiency of 89.56%. Comparing the two substrate materials, the antenna design utilizing Rogers RT5880 material demonstrates improved gain, higher directivity, wider bandwidth, lower return loss, lower VSWR, and higher efficiency than the FR-4 material. These performance characteristics make the antenna design utilizing Rogers RT5880 material a more appealing choice for potential 5G wireless applications. Table 2 summarizes the simulation results, providing a concise overview of the findings.

Table 2: Provides an Overview of the Results of the Simulation

FR-4 substrate		Rogers RT5880
Parameter	**Value**	**Value**
Return Loss (dB)	-17.072	-13.772
Bandwidth (GHz)	0.1209	0.0236
Gain (dBi)	3.321	7.55
Directivity (dBi)	7.57	8.43
Efficiency (%)	43.88%	89.56%
VSWR	1.3294	1.5152

Tables 3 and 4 compare the proposed MPA's maximum return loss, maximum gain, directivity, efficiency, and bandwidth. This comparison may be found under "Maximum Return Loss" and "Maximum Gain." This solution may be a good fit for the growing demand for wireless communication technology, leading to the rise in demand for wireless communication technology.

Table 3: The Difference between the Planned Design and the Previously Published Works

Ref.	Return loss (dB)	Gain (dB)	VSWR	BW(GHz)
[9]	-19.37	3.05	1.2411	490MHz
[12]	-21.8	6.62	1.117	-
[20]	-21.73	6.32	1.23	-
[21]	-30.9	-	1.059	-
[22]	-12.54	5.5	1.6	66.5MHz
[23]	-26.347	-	1.10	64 MHz
[24]	-17.436	3.68	1.31	65.2MHz
[25]	-19	-	-	20 MHz

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[26]	-15.8	-	-	67.4 MHz
This Work	**-17.072**	**3.321**	**1.3294**	**0.1209**
	-13.772	**7.55**	**1.5152**	**0.0236**

Table 4: Comparison between the Previously Published Works and Proposed Work

Ref.	Dielectric Permittivity (ε)	Thickness (mm)	Efficiency (%)
[9]	-	1.6	60.27%
[12]	2.2	1.575	89%
[27]	4.3	1.6	46.5%
[28]	4.3	1.6mm	75.70%
	2.2	1.57mm	60.13%
	3	1.58mm	61.51%
This Work	**4.3**	**1.6**	**43.88%**
	2.2	**0.077**	**89.56%**

6. CONCLUSIONS

This research evaluated the performance of a microstrip patch antenna (MPA) designed for wireless communication systems, especially WLANs and mobile phones. The modeling results of the proposed MPA include parameters such as return loss, directivity, gain, and VSWR. The antenna demonstrates high efficiency, making it competitive compared to other antenna designs. It significantly improves broadband performance, gain, return loss, and radiation efficiency compared to alternative methods. Therefore, the constructed antenna presented in this paper is an excellent candidate for wireless applications. The increasing demand for practical antennas in remote networks, particularly in wireless applications, has successfully met the antenna's performance parameters. The simulation results indicate that the suggested antenna has the potential to meet the requirements of wireless communication systems effectively. Fabricating the antenna and contrasting its measured results with the predicted outcomes will provide additional validation. This experimental verification process will provide valuable insights and further confirm the antenna's suitability for real-world applications.

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