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# A review on microstrip patch antenna for wireless communication systems at 3.5 GHz

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**ABSTRACT**

This article presents a review of several microstrip patch antennas for 3.5 GHz wireless applications. Different substrate materials, FR-4 (loss), FR-4 Epoxy, Rogers RT/droid 5880, TLC-30, and Rogers RT/droid 5880 LZ, are used. In recent years, wireless antenna applications have increased, including biomedical appliances, internet of things (IoT) terminals, edge devices, radars, mobile phones, and many more. In this work, several articles were reviewed and investigated, and several microstrip patch antennas with a resonance frequency of 3.5 GHz were designed using different substrate materials and shapes. This article also discussed the geometric shapes of antennas, antenna properties, sizes of substrate materials, loss tangent, thickness, return loss, bandwidth, voltage standing wave ratio (VSWR), gain, efficiency, and directivity. Several software is used for design and simulation, including computer simulation technology (CST), high-frequency simulation frequency (HFSS), and advanced design system (ADS), FEKO, and MATLAB. The main goal of this paper is to talk about different wireless application papers that work in the S-band at a frequency of 3.5 GHz and have been published in various international journals and conferences.



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## 1. INTRODUCTION

In recent years, there has been much interest in microstrip patch antennas because they are compact, have low profiles, are simple to integrate, are reasonably priced, and perform exceptionally well. This antenna is designed for WiMAX and other forms of wireless communication due to the continual expansion of wireless communication services and the continued miniaturization of communication equipment. On the other hand, these antennas have several problems, the most important of which are their low gain, low power, and narrow bandwidth [1]. In most applications, patch antennas have largely replaced giant antennas as the preferred choice. Patch antennas can take on a variety of configurations, including those that are triangular, circular, rectangular, fractal, and so on. A unique combination of qualities, constraints, benefits, and drawbacks distinguishes each [2]. Figure 1 [3], [4] shows the configurations of different shapes of microstrip patch antennas, which are Figure 1(a) is rectangle, Figure 1(b) is square, Figure 1(c) is circle, Figure 1(d) is triangle, Figure 1(e) is donut, and Figure 1(f) is dipole.

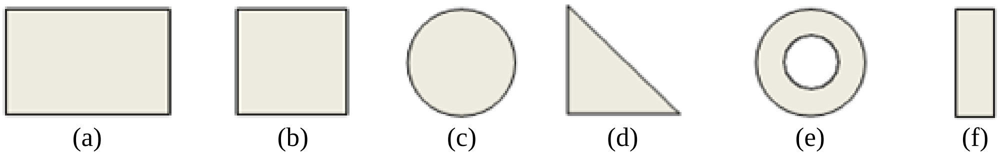


Figure 1. Different shapes of microstrip patch antenna, (a) rectangle, (b) square, (c) circle, (d) triangle, (e) donut, and (f) dipole

Microstrip antennas have been improving for a long time, and the number of ways to use them keeps growing. This microstrip technology is experiencing significant growth [5]. The field that deals with wireless communication is called "the *airwaves*". In recent years, the size of electronic devices has shrunk dramatically, and at the same time, their usefulness has increased for a wide variety of applications [6]. He antennas required for a wide variety of applications relating to communication should have the characteristics of being small, lightweight, and low-profile. In wireless communication, they can be utilized in various ways [7].

The paper is organized into seven (7) sections. Section 1 is an introduction, and the section 2 details the microstrip patch antenna. Furthermore, the section 3 discusses antenna return loss; the section 4 discusses antenna voltage standing wave ratio (VSWR), antenna radiation pattern, gain, and surface current. Section 5 discusses the literature review of the entire paper. Also, an analysis of previously published works is discussed in section 6. The document's conclusion is discussed in section 7. Finally, references and authors' biographies are given in the last section.

## 2. MICROSTRIP PATCH ANTENNA

The microstrip antenna patch antenna was a completely original design that only existed in 1955. A microstrip antenna is made up of a portion of the substrate that is composed of a dielectric substance and is sandwiched between two plates of conducting material. Although the lower bearing surface is also known as the ground plane, the higher conducting plate is referred to as a patch. Both of these terms are used interchangeably. Because the fabrication process for microstrip antennas is comparable to that of printed circuit boards, the term "printed antennas" is occasionally used to refer to these antennas. There are a number of aspects that determine the performance of the microstrip antenna, with the size and contour of the patch being two of the most essential of these elements. The performance of a microstrip patch antenna is reliant on various factors, including its length, width, substrate thickness, the dielectric constant of the substance that makes up the substrate, and the placement of the feed line [8]. The construction of the microstrip patch antenna is illustrated in Figure 2.

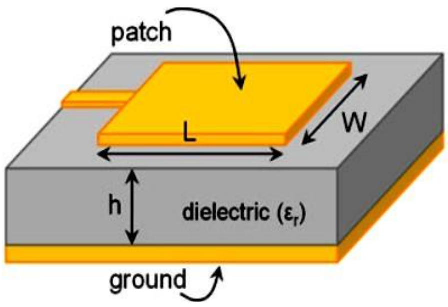


Figure 2. Microstrip patch antenna's overall geometric layout

The microstrip patch antenna, also known as an MPA, is constructed by stacking the substrate and the metal in a three-layer stack. Copper or another material with solid conductivity is often used to build the ground structure, which is the layer that is the lowest in the system. In addition to air, FR4, Rogers, or any other dielectric substrate, the intermediate substrate layer may also be something else. The topmost layer, often known as the patch or design layer, is either composed of a substance that is highly conductive or uses copper as its foundation [9], [10]. Figure 3 shows all microstrip antennas can be organized into one of these four primary categories [11].

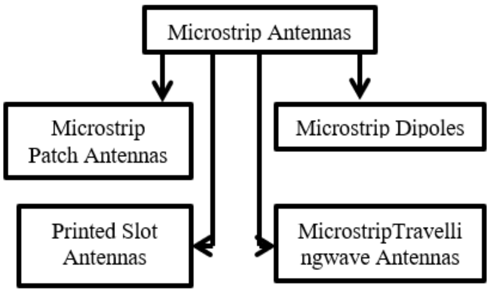


Figure 3. Categories of microstrip antennas

Figure 4 shows the microstrip line feed patch antenna. It is one of the easiest ways to make a line feed because all you need is a conducting strip connected to the patch. Because of this, it may be considered an extension of the patch itself. Also, Figure 5 shows a proximity-coupled microstrip patch antenna. The bandwidth of proximity coupling is the largest, producing very little spurious radiation. The width-to-length ratio of the patch as well as the length of the feeding stub, determines the control of the match. The nature of its coupling mechanism can be described as capacitive [11].

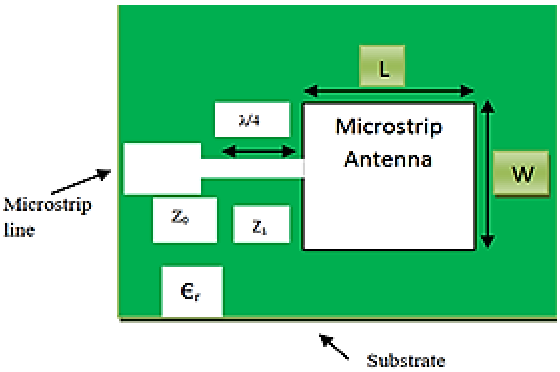


Figure 4. Patch antenna with microstrip line as the feed

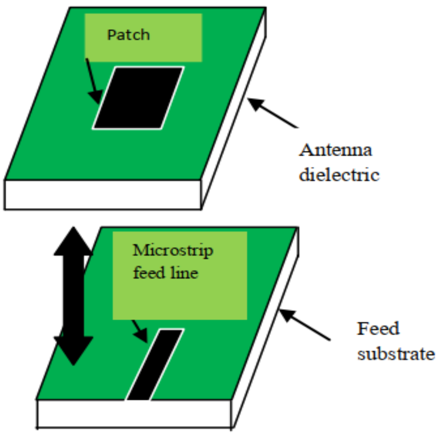


Figure 5. Microstrip patch antenna that is connected by proximity

## 3. RETURN LOSS

Return loss is a measurement that determines how efficiently electricity is transferred from a transmission line to a load like an antenna. Let's say the power that hits the antenna under test (AUT) is watts, and the energy reflected in the source is $P_{ref}$ watts. In this scenario, the ratio x/y displays the influence of the traveling wave and represents the mismatch between the occurrence and the observation. The load and the line are more effectively matched when this power ratio is higher [12]. The return loss is measured in decibels, and its definition is as:

$$\text{Return loss (RL)}=10\log_{10}\left(\frac{P_{in}}{P_{ref}}\right)\text{ dB}$$

Which is a positive quantity if the comparison shows that $\mathrm{P_{ref}} < \mathrm{P_{in}}$. To put it another way, RL can be thought of as the difference, expressed in decibels, between the power directed towards the AUT and the energy reflected. The return loss value must be less than -10 dB for accurate impedance matching, which is ideal for mobile or wireless technology. It has been set to the necessary frequency for the antenna to work correctly. Also, the S-parameter is the most straightforward method for explaining the input and output of the signal sources and the fact that not all the power generated is sent to the load [13], [14].

## 4. VSWR, RADIATION PATTERN, GAIN, AND SURFACE CURRENT

The ratio between maximum and minimum voltage is known as the VSWR. No power is reflected from the source when the VSWR equals 1:1. This is a picture-perfect scenario that only some people, if ever, get to experience in real life. In almost all circumstances, a VSWR of 1.2:1 (or 1.2) is considered outstanding in the real world. The number 1.2:1 for the VSWR signifies that the maximum standing wave amplitude is 1.2 times bigger than the minimum standing wave value [15]. It is a measure of the power that the antenna reflects. The value of the VSWR should be a number that is both positive and actual. The lower the VSWR number, the better the antenna's performance. It elucidates the method used to match the impedance of the transmission line. The VSWR bandwidth should have a value that is neither greater than 2 nor lower than 1. In the best possible scenario, it is 1. In the ideal case, it is 1 [16].

In the process of determining how well a microstrip patch antenna performs, the radiation pattern is the most significant and distinguishing feature to keep in mind. Therefore, it is an essential metric since it explains how well the antenna operates. The gain of an antenna is a crucial component in determining its overall performance. Measuring or determining the payment of an antenna is only achievable in some conditions that occur in the real world. It is also becoming increasingly critical for system engineers to estimate antenna sizes precisely as the number of wireless applications continues to rise in popularity [17]. The gain must be positive for the antenna to work well in the frequency band for important wireless communication [18]. An electromagnetic field outside the water causes the surface current, a natural electric current [13]. This makes the electric surface current density on the conducting surfaces unknown and the electric and magnetic surface current densities on the dielectric surfaces strange. These currents and the wind that blows through the dielectric zone are what cause the electric and magnetic fields in the area [19].

## 5. LITERATURE REVIEW

As the number of people using wireless communication has grown, service providers have had to deal with many problems before offering better services to their clients. The number of services that can be provided has increased with each new generation of wireless technology. Some of the services that the internet of things (IoT) provides, for example, offer more bandwidth, faster connections, and more security features to make communication easier. The wireless sector has progressed from analog to digital systems, such as the second generation. With the third generation, features like global roaming and wideband bandwidth were added, and applications like TV and video were made possible. The sector's expansion resulted in the developing of fourth-generation (4G) technology, which enhanced video calling capabilities, mobile television, and video broadcasting services. The requirement for fifth generation (5G) results from improved performance in the wireless industry. It can provide more power to technology than previous generations could manage. The advent of 5G technology could pave the way for the rise of robotization. Healthcare is delivered remotely with gadgets connected to the IoT. The microstrip patch antenna element is an excellent candidate for the 5G antenna [20].

The need for modern wireless devices was too great for 4G of wireless communication systems, so engineers made the 5G of wireless communication systems. The most important things about 5G are its fast data rates, large capacity, high reliability, and low latency. Because the devices we have now can't meet the needs of 5G, we'll have to make new ones with unique designs and features. Most people agree that the antennas' special features are some of the most noticeable parts of the new designs. But there are a lot of problems that need to be solved before antennas that can be used for 5G applications can be made. Many different bands can be used, including a beam scanning capability with wide angles, ultra-wideband circularly polarized antenna elements, high-gain, low profile, and possibly being manufactured cheaply. These are some of the advantages. Another advantage is that many different bands can be used [21].

The global positioning system (GPS), wireless local area networks (WLANs), microwave sensors, and mobile communication systems are all examples of applications that make use of patch antennas. Microstrip antennas have the potential to generate favourable outcomes in terms of bandwidth, resonant frequency, gain, impedance, and return loss when the appropriate microstrip antenna design is utilised, and the relevant slots are positioned in the ideal locations. Feeding tactics are used to provide an antenna with a source so that it can perform its purpose. A microstrip feed line technique, a coaxial feed technique, an aperture coupling feeding technique, and a proximity coupling technique are the four approaches that are going to be explored in this article [22]. This section will discuss many kinds of 3.5 GHz microstrip patch antennas published in international journals and conferences. Several authors have written high-quality papers about microstrip patch antennas for international journals and conferences, and they have been talked about.

Based on Ali *et al.* [23], designs and simulations are done, the operating frequency of which is 3.5 GHz, which is used in 5G technology. This technology could make 5G networks faster and more reliable, with wider bandwidths and connection points. To reach its full potential, problems with network coverage, user experience, and the network's ability must be convincingly solved. These issues will have repercussions for all mobile network operators and system vendors. The antenna's design came from an older one, but the background and patch size were changed to make it work better. Rana *et al.* [24] shows how to make a microstrip patch antenna that works at 3.5 GHz for future wireless communications. Through this study, 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 has been designed for use in various wireless communications, such as satellites, weather radar, ship radar on the surface, wireless LANs, multimedia applications in mobile TV, and other wireless fidelity applications.

Singh *et al.* [25] discusses a single-layer slotted microstrip patch antenna in the shape of an arrowhead that has been thoroughly simulated for usage in wireless communications systems operating at 3.5 GHz. It was a rectangular microstrip patch antenna with slots shaped like an arrowhead. The proposed antenna has a small footprint and can cover the wireless network, WLAN, and Bluetooth applications with high efficacy. An E-shaped rectangular fractal antenna model is offered here [26] for your perusal and consideration. The microstrip line feeding technique is a method of feeding the antenna. Gain, return loss, VSWR, and bandwidth are antenna properties that can be modelled and tested. The antenna built is flexible and can be used for different wireless applications, such as WLAN, space communications, long-distance communications, and so on.

Al Amin *et al.* [27] designed and analysed a rectangular microstrip patch antenna to maximize the profit by minimizing the loss on the return. When it comes to an antenna with a rectangular feed probe, putting the search in the right place ensures that the return loss is as low as possible while giving the antenna the gain it needs. So, the rectangular microstrip patch antenna did a great job of reducing growth and increasing return loss. Ferdous *et al.* [28] presents the design and construction of a low-profile patch antenna that is intended for use in the implementation of 5G communication systems that operate at 3.5 GHz. In addition to the S-parameter, antenna gain, directivity, and efficiency, a number of other metrics have been observed. A valuable device for both sending and receiving messages, the antenna has a gain that is larger than 5 decibels. Adapting the antenna to meet the requirements of applications that require access to 5G networks is the primary focus of the design.

Paragya and Siswono [29] designed a microstrip antenna with a frequency of 3.5 GHz for 5G applications. The primary features sources were an essay from the Rel-15 3rd generation partnership project and the views of Huawei and Qualcomm on different public policy issues. The method starts with figuring out how big the antenna should be initially and ends with simulating and improving it. The first thing that happens in the simulation is a representation of the first measurement. The next step is to utilize the method of close-coupled feeding, which comes after that. Ibrahim *et al.* [30] demonstrate how a rectangular patch antenna array could be utilised in a 5G application. When operating at a frequency of 3500 MHz, the antenna design generates a satisfactory return and a satisfactory insertion loss. When contrasted with the creation of a single element, the performance of the array structure was significantly superior. Band 78 is a portion of the 5G spectrum that is used quite regularly, and the compensated antenna is capable of functioning across a frequency range that encompasses this band.

This small T-shaped microstrip antenna could be used in the 5G wireless communication system [31]. The bandwidth of an antenna made with a standard microstrip patch was limited, so a T-shaped microstrip patch was made to fix the problems this caused. Because it matches the optimal impedance at various frequencies, this structure maintains its radiation characteristics across different frequency ranges. It is possible to increase the frequency range of the low-frequency band by drilling a hole in the ground in the shape of a rectangular T. When simulating and analyzing, the CST microwave study looks at different properties, such as the radiation pattern, the reflection coefficient, the gain, the current distribution, and the efficiency of the radiation. The suggested antenna functions well for wireless connections, including mobile ones that use 5G.

A new way to use a 5G network's (CPA) proximity-coupled fed microstrip circular patch antenna operating at 3.5 GHz [32]. The proposed antenna's impedance matching and return loss characteristics are of an incredibly high calibre. The VSWR is very close to what it should be, and the CPA simultaneously has both efficiency and capacity. This CPA is appropriate for various 5G applications because its design is straightforward and compact, maintains a high gain, has good radiation properties, includes the proper impedance matching, and contains the correct impedance matching. Al-Gburi *et al.* [33] recommended that the hexagonal-shaped slotted array antenna for use in 5G applications. The technique already in place started with making one element and moved on to making 1x8 array elements as time passed. The 1x8 array antenna of the planned feed line gets power from an existing microstrip corporate feed line. The suggested hexagonal patch antenna could be a good alternative for 5G wireless systems based on how well the antenna works.

Cirik and Yildirim [34] designed an antenna for WiMAX with a high gain and a microstrip patch that runs at 3.5 GHz. The gain of the patch antenna, measured at 3.5 GHz, is around 3.6 decibels compared to the ideal situation. When a parasitic radiator is added to the top of a patch antenna, the antenna's gain increases from about 3.6 decibels to approximately 7.4 decibels. Even when not paired with a radio-frequency amplifier, the gain increases by about 5.3 dB. Chen and Lin [35] showed how to build a 2x2 microstrip patch array antenna that can work as a 5G C-band access point. When it comes to handling applications that require 5G C-band performance, the array makes use of a rectangular microstrip antenna that has two vertical slots. As an extra part, the design includes a microstrip feed network to send power to the antenna array. An antenna array with a low profile and an easy installation method is an excellent choice for applications that need to install 5G C-band access points.

To create a microstrip patch antenna that operates at 3.5 GHz, used three distinct substrate materials, each of which had a relative permittivity that was distinct from the others [36]. The reflection coefficient, VSWR, bandwidth, gain, and efficiency of these devices are all taken into consideration in this process. A number of different antenna designs attempted to achieve a reflection coefficient that was lower than -10 dB while maintaining a gain and bandwidth that were satisfactory by whatever means necessary. Gupta *et al.* [37] studied the properties of the new antenna in a model of a rectangular microstrip patch antenna with air as the substrate has been proposed. The designed antenna's return loss, bandwidth, directivity, gain, radiation pattern, and VSWR were all looked at. This antenna shows a great deal of promise for use in microwave communications.

Kumar *et al.* [38] presented the design of a straightforward microstrip patch antenna in using advanced design system (ADS) at a resonant frequency of 3.55 GHz. This antenna is well-suited for use in WLAN applications and applications involving satellite communications and WiMax. The findings indicate an increase in bandwidth, gain, and return losses. The graphic representation of the results demonstrates an improvement in efficiency and broader radiation patterns. Rasheda *et al.* [39] proposed a genetic algorithm into optimize a fractal square microstrip patch antenna with the partial ground at 3.5 and 6 GHz. The results of this optimization are presented. Compared to the non-optimized version, the optimized antenna design produces significantly better performance. The optimal findings were provided, primarily focusing on the gain, VSWR, and rerun loss. As a result, the design that has been optimized is appropriate for use in both the S-band and the C-band.

Research by Hamzidah and Setijadi [40], looks at how a standard microstrip antenna and an antenna made by computer simulation technology (CST) microwave that uses complementary split-ring resonator (CSRR) cells compare their parameters and how well they work. Both are built to exact specifications and run at a frequency of 3.5 gigahertz. Based on the simulation results, the microstrip antenna with a CSRR metamaterial cell has better return loss, VSWR, gain, bandwidth, impedance reference, and radiation pattern than the traditional microstrip antenna. When put on an antenna, CSRR metamaterial cells improve performance and reduce the antenna size, making it 49.44% smaller than a standard microstrip antenna. The fact that the antennas are visible in the image indicates this. It is anticipated that it will apply to the WiMAX standard.

Research by Sahithi *et al.* [41] proposed a U-slot microstrip patch antenna for WiMAX applications that have been shown to work better regarding bandwidth. It is composed of a symmetrical U-shaped slot and a rectangular patch. In this study, the way the device works and how it was made are broken down in a lot of detail. The results indicate that the u-slot antenna has a band with a frequency range of 3.5 GHz to 3.7 GHz and can get low voltage while maintaining a good bandwidth and radiation quality. A microstrip antenna that can work at a 3.6 GHz resonance frequency has been built. Ajay and Mathew [42] used HFSS in to build a traditional patch antenna and a metamaterial-based antenna with a resonant frequency of 3.5 GHz. Several performance parameters were then studied. Comparing the results of measurements and simulations showed that a metamaterial-based antenna worked the way it was supposed to. The size of the metamaterial antenna is cut down to 58.2% of what it was before, and the return loss is improved by about 10%. Authors of this paper [43], altered the antenna designs to get a higher gain in the frequency band planned for use by 5G mobile applications in India. The proposed antenna can be built for very little money and still work well in terms of gain and efficiency. This is possible thanks to the antenna's modular design. Ansoft's HFSS software was used to test the proposed antennas. This software is available for sale. The bandwidth, gain, return loss, VSWR, and radiation pattern are all examined to determine how well the antenna works. The design of a rectangular microstrip line-fed patch antenna array for WiMAX and unmanned air vehicle (UAV) applications is presented in [44]. The center frequency of the array is 3.8 GHz. The results of the designed antennas were compared in terms of return loss, bandwidth, directivity, gain, and radiation pattern.

## 6. ANALYSIS OF THE PREVIOUSLY PUBLISHED WORKS

Researchers are currently focusing more on microstrip patch antennas. One reason is that many types of software can be used for antenna design. Also, the antenna can be manufactured cheaply and in less time. People's demands for wireless applications are increasing daily. One of them is this patch antenna. The antenna is a vital part of wireless communication. It sends an electromagnetic wave between two points to connect them. Antennas are utilized in various settings and configurations, and their utilization is prevalent. Return loss, gain, directivity, VSWR, surface current, efficiency, and bandwidth are all aspects of performance that can be expected from the antenna [45]. At 3.5 GHz, the values for dielectric permittivity, return loss, directivity gain, VSWR, and bandwidth are all listed in Table 1.

Table 1. By comparing various previously published works at 3.5 GHz

| Ref | Operating frequency (GHz) | Dielectricity permittivity ($\varepsilon$) | Return loss (dB) | Directivity gain (dBi) | VSWR | Bandwidth (MHz) |
|---|---|---|---|---|---|---|
| [29] | 3.5 | - | -17.436 | 6.6 | 1.31 | 65.2 |
| [30] | 3.5 | 2.2 | -18.02 | - | - | 120 |
| [31] | 3.6 | 2 | -28.76 | 2.52 | Below 2 | - |
| [32] | 3.5 | 2.2 | -40.2827 | 5.82 | 1.02 | 200 |
| [33] | 3.5 | - | -2.12 | 5.43 | - | - |
| [36] | 3.5 | 4.3 | -28.48 | 3.33 | 1.078 | 247.1 |
| | | 2.2 | -14.13 | 4.66 | 1.48 | 129.7 |
| [37] | 3.525 | 1.5 | -40.965 | 6.6 | 1.0328 | 140.6 |
| [38] | 3.55 | 4.6 | -19 | 7 | - | 20 |
| [42] | 3.5 | 2.2 | -15.8 | 6.98 | - | 67.4 |
| [43] | 3.5 | 4.4 | -29.5 | 3 | 1 | 300 |
| [44] | 3.8 | - | -18.2 | 13.5 | Less than 2 | 72 |
| [45] | 3.5 | 2.2 | -26.385 | - | 1.09 | 72 |
| [46] | 3.5 | - | -21.8 | 7.2 | 1.117 | 0.210 |
| [47] | 3.55 | - | -44 | 6.69 | 1.0238 | - |
| [48] | 3.5 | 4.4 | -43.52 | 2.82 | 1.01 | 2,300 |
| [49] | 3.5 | 4.3 | -12.54 | 5.5 | 1.6 | 66.5 |
| [50] | 3.5 | 2 | -29 | 6 | - | - |
| [51] | 3.5 | 4.3 | -26.2 | - | - | - |
| [52] | 3.5 | 4.4 | Less than -10 | 2.60 | - | 400 |
| [53] | 3.9 | 2.2 | -68.68 | 3.30 | 1.007 | 1,420 |
| [54] | 3.6 | 2.2 | -44.97 | 8.298 | 1.011 | 92.28 |
| | | | -17.622 | 9.924 | 1.304 | 204 |
| [55] | 3.5 | 4.3 | -41.74 | 3.4 | - | 500 |
| [56] | 3.5 | 4.4 | Below -10 | 1.2 | - | 71 |
| [57] | 3.5 | - | -30 | 8 | 1.5 | - |

## 7. CONCLUSION

A complete review of recent novel microstrip patch antennas with a frequency of 3.5 GHz is presented in this article using different substrate materials and shapes. These antennas also had dynamic relative permittivity. Based on the simulation results, these antennas can work simultaneously on two and three bands with a high directivity gain, the lowest return loss, a wide bandwidth, and high radiation efficiency. These papers have been used in many fields, such as wireless communications, biomedicine, machine learning, wireless power transfer, the IoT, artificial intelligence, and more. Among the applications, microstrip patch antennas are most commonly used in wireless communications systems, such as 5G. Simulations are run using CST, HFSS, MATLAB, FEKO, and ADS to get the results.

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