At 28 GHz microstrip patch antenna for wireless applications: a review

Md. Sohel Rana[1,2,3], Piyal Mistry[1], Md. Jahidur Rahaman[1], Sahriar Islam Shipon[1], Shake Zion Haider Ovi[1], Md. Masud Rana[1], Tahasin Ahmed Fahim[4]

[1]Department of Electrical and Electronic Engineering, Northern University of Business and Technology Khulna, Khulna, Bangladesh
[2]Department of Electrical and Electronic Engineering, Independent University, Bangladesh, Dhaka, Bangladesh
[3]Department of Computer Science and Engineering, Bangladesh University of Professionals, Mirpur, Bangladesh
[4]Department of Electrical and Electronic Engineering, Noakhali Science and Technology University, Noakhali, Bangladesh

Article Info

Article history:

Received Mar 2, 2023
Revised Dec 21, 2023
Accepted Jan 5, 2024

Keywords:

Bandwidth
Cell phones
Return loss
Super-high-frequency
Voltage standing wave ratio
Wireless communications systems
Wireless local area networks

ABSTRACT

Microstrip patch antennas are becoming increasingly popular because they are small, have low profiles, are easy to integrate, are very cheap, and work well. For this reason, this antenna could be used for wireless communication systems. This research paper reviews and studies 28 GHz microstrip patch antenna for wireless applications. Different substrate materials have been used to make these antennas, such as FR-4 (loss), FR-4 Epoxy, Rogers RT/droid 5880, TLC-30, Rogers RT/droid 5880 LZ, and others. Different substrate materials and shapes were used to make microstrip patch antennas with a frequency of 28 GHz. This article discusses the different sizes of antennas, the other geometric shapes antennas can take, the different ways antennas' properties can be analyzed, and the different types of antennas. It will also talk about the material, thickness, loss tangent, return loss, bandwidth, voltage standing wave ratio (VSWR), gain, efficiency, and directivity of the substrate. This antenna is used for super-high-frequency (SHF), radars, commercial wireless local area networks (LANs), cell phones, and other wireless communications systems.

Corresponding Author:

Md. Sohel Rana
Department of Electrical and Electronic Engineering, Northern University of Business and Technology
Khulna-9100, Bangladesh
Email: sohel.rana@uits.edu.bd

1. INTRODUCTION

Antenna design is becoming increasingly difficult in today's society due to the growing need for wireless communication systems and the subsequent shrinking of these systems [1]. In the last few decades, wireless technology has quickly come a long way. All improvements in wireless communication are driven by antennas, which serve as the backbone and the driving force. The antenna is part of a wireless communication system that connects to the channel, which is the part that is most likely to get messed up. Patch antennas, also called microstrip antennas, are one of the most common types. They are popular because they have a low profile, can be bent, are easy to make, are cheap, small, and can be used in many different ways. Because of this, they have been used in a wide range of helpful ways [2]. Some of the antennas shown in the research are a monopole antenna, a dipole antenna, a reflector antenna, a microstrip antenna, and a folded dipole antenna [3].

In the 1970s, microstrip antennas became the main form of antenna, particularly for use in projects carried out in space. In modern times, they are put to use in a variety of commercial and governmental contexts. These antennas are made out of a metallic patch placed on top of a grounded substrate [4].

The overall shape of a patch antenna is illustrated in Figure 1 [5]. Figure 2 is a diagram that illustrates the many different shapes of microstrip patch antennas. It shows that a square, a dipole, a rectangular patch, a circular patch, a triangle and an elliptical patch with a coaxial probe feed are used to evaluate and contrast the performance of that antenna [6]. In most cases, the microstrip patch antennas are constructed out of metallic patches with a wider width and a substrate with a lower dielectric constant but a higher height. Excitation for the microstrip patch antenna might come from a 50 Ω coaxial connector or a microstrip line. The dimensions of the radiating patch affect the resonating frequencies of the antenna. The height of the substrate (h), the length of the patch (L), and the relative dielectric constant (ε_r), are all examples of these parameters [7]. In addition, the antenna design is one of the most difficult challenges in providing support for future fifth generation (5G) cellular connectivity. It is necessary to have an antenna that is both effective and based on high performance if one wishes to improve the performance of mobile communication. The microstrip patch antenna is one of the most frequent types of antenna, and it is commonly used because it is inexpensive, has a tiny size, and is relatively lightweight [8].

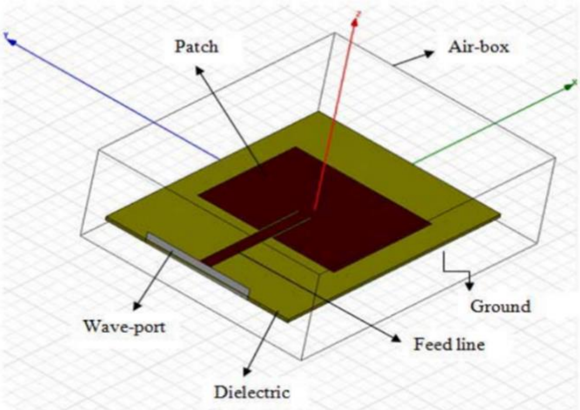


Figure 1. Microstrip patch antenna’s geometrical foundations

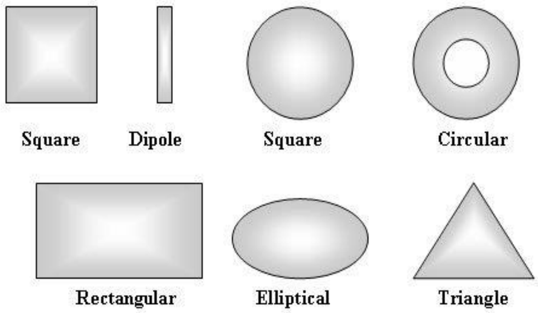


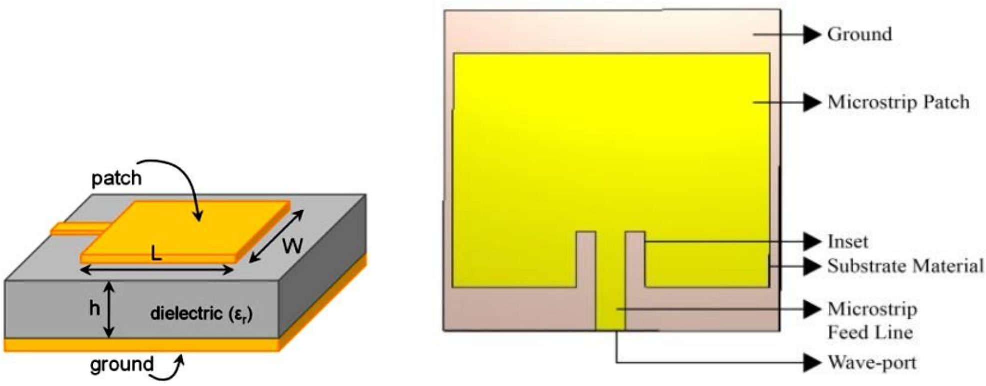
Figure 2. Several distinct configurations for microstrip patch antennas

Antennas are being used for communication, navigation, directing, and warning in greater numbers as a direct result of the rapid expansion of contemporary radar and communication systems. Because of this, the system becomes bulkier, busier, more intricate, and more energy-intensive, all of which are detrimental to its standard operation and performance. Because these technical issues are so complicated, it is recommended that only one antenna be used but that the structure of that antenna be changed in real time so that it can work with multiple antennas [9].

The entire paper is divided into six sections. Section 1 presents an introduction. Section 2 discusses the microstrip patch antenna. In section 3, parametric studies of microstrip patch antennas are discussed. Besides the literature review, this is addressed in section 4. Section 5 discusses the analysis of previously published works, and section 6 gives the conclusion. References to various papers are presented in the next section. All authors’ biographies are offered at the end.

2. MICROSTRIP PATCH ANTENNA

Microstrip patch antennas have many uses, especially in medicine, the military, mobile, satellite communications, wireless communications, and a number of other areas [6]. In 1955, a new type of antenna called a microstrip antenna, also called a patch antenna, was invented. A microstrip antenna is constructed from a piece of substrate made of a dielectric material and positioned between two plates of conducting material. These three components come together to form the antenna. Microstrip antennas are frequently referred to as “printed antennas” since the fabrication method is comparable to printed circuit boards. A microstrip patch antenna’s performance is determined by several elements, such as its length, width, substrate thickness, the dielectric constant of the substance that makes up the substrate, and the placement of the feed line [10]. Figure 3 illustrates the building of the microstrip patch antenna; Figure 3(a) physical construction of microstrip patch antenna (MPA) and Figure 3(b) MPA designed using CST software illustrates the building of the microstrip patch antenna. The metal and the substrate are layered three times to produce the MPA and form a stack. The ground structure, the lowest layer, is often made of copper or another material that conducts electricity well. The substrate layer sometimes referred to as the intermediate layer, can be constructed out of the air, FR4, Rogers, or any other type of dielectric substrate. The top layer, called the patch or design layer, is highly conductive, usually copper. This layer is the only one that can be seen from the outside [11], [12].



(a) (b)

Figure 3. Microstrip patch antenna’s overall geometric layout: (a) physical construction of MPA and (b) MPA designed using CST software

3. PARAMETRIC STUDIES

Microstrip patch antennas have been a subject of study and interest in the business and academic worlds since they were first introduced. Microstrip patch antennas have become increasingly popular in printed circuit board (PCB) designs due to their advantageous characteristics, which include their small size, low fabrication cost, and lightweight nature [13]. In that section, various parameters of microstrip patch antennas are discussed. Some parameters are return loss, voltage standing wave ratio (VSWR), radiation pattern, gain, bandwidth, surface current, and efficiency. In that section, various parameters of microstrip patch antennas are discussed. Some parameters are return loss, VSWR, radiation pattern, gain, bandwidth, surface current, and efficiency.

3.1. Return loss

Return loss is typically synonymous with the reflection coefficient, represented by the symbol S_{11} (return loss). This coefficient shows how the input and output ports work together and how much power is reflected from the antenna. The return loss plot shows how the feedline and antenna should be matched. If the return loss is 0 dB, it indicates that the antenna reflects all of the power and that none is being radiated into the surrounding space. For the antenna to deliver an effective performance, the value of S_{11} must be at least -10 dB. The return loss value shows how well the antenna works; a lower number means better performance [13]. Let’s say the power that strikes the antenna being evaluated (known as the AUT) is P_{in} watts, and the energy reflected into the source is also P_{ref} watts. When this power ratio is higher, the load and the line are matched up more effectively [14]. The return loss is measured in decibels, and its definition is as:

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

Which is a positive quantity if the comparison shows that $P_{ref} < P_{in}$. The return loss value must be less than -10 dB for accurate impedance matching. This is a perfect condition for mobile or wireless technology. It has been set to the right frequency, so the antenna can do what it needs. Also, the parameter is the method that best explains how the signal sources send and receive signals and why not all of the power created is sent to the load. This is because the parameter is the most straightforward method [15], [16].

3.2. Voltage standing wave ratio

The ratio of the antenna's maximum to minimum voltage is known as the voltage standing wave ratio [17]. When the VSWR is 1:1, the source hasn't reflected any power. In the real world, a VSWR of 1.2:1 (or just 1.2) is almost always considered excellent. The ratio of 1.2:1 between the greatest standing wave amplitude and the minimum standing wave value denotes that the maximum standing wave amplitude is 1.2 times greater than the minimum standing wave value [18]. This metric is used to evaluate the amount of power reflected by the antenna. It is recommended that the value of the VSWR be a figure that is both positive and actual. It explains the procedure utilized to match the impedance of the transmission line. The value of the VSWR bandwidth shouldn't be any higher than 2, and it shouldn't be any lower than 1. It would be 1 in a perfect scenario [19]. VSWR can be used to find problems in transmission lines [20].

3.3. Radiation pattern, gain, bandwidth, and surface current

The amount of energy radiated from the antenna is represented by the pattern of radiation that the antenna produces [13]. Gain is calculated by multiplying an antenna's directivity by a factor that shows how well it sends out waves. This efficiency is measured as the radiated power (P_r) ratio to the total power applied to the system (P_i). Due to the conductor and dielectric losses in the materials used, some of the power that is put in is lost. In contrast, the rest of the power is changed into radiated and surface wave power. This total efficiency is made up of both the efficiency of the antenna's radiation and the efficiency of its impedance matching. Another important part of how an antenna is made is the range of frequencies it can cover. The impedance bandwidth is typically the only parameter that is supplied [21].

The gain of an antenna is the most important indicator of it is overall performance. But it is only possible to accurately measure or figure out an antenna's gain in some real-world situations. Also, the growing use of wireless applications has made it more important for system engineers to estimate antenna sizes accurately [22]. For the antenna to work well in the frequency band needed for important wireless communication, it needs to have a positive gain [23]. The surface current is a naturally occurring electric current that is brought about by an electromagnetic field that is located above the water [15]. As a result, the electric surface current density on the conducting surfaces is unknown, and the electric and magnetic surface current densities on the dielectric surfaces are weird. These currents, in addition to the wind that blows across the dielectric zone, are the primary causes of the electric and magnetic fields that may be found in the region [24].

3.4. Efficiency and radiation efficiency

The term "efficiency" refers to the amount of energy that needs to be put into an antenna for effective communication [25]. 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. The vast majority of the power sent to an antenna with low efficiency is either lost due to losses within the antenna itself or is reflected away due to an impedance mismatch [26].

$$\therefore Antenna\ efficiency = \frac{\text{Gain (dBi)}}{\text{Directivity(dBi)}} \times 100\%$$

To calculate the total efficiency of an antenna, one must first multiply the radiated efficiency of the antenna by the impedance mismatch loss that occurs when the antenna is connected to a transmission line or a receiver [27]. The ratio of the total power that the antenna sends out to the net energy it receives from a linked transmitter is used to calculate the antenna's radiation efficiency [28].

4. LITERATURE REVIEW

Wireless applications in the modern world make it hard for antenna engineers to make small antennas that still work well and are cheap and easy. How an antenna is fed, the best place to feed it, and the right design parameters all greatly impact how well it works. The most common ways to feed single-layered patch antennas are inset feeding, strip line feeding, edge feeding, and coaxial feeding [29]. These antennas are essential in establishing a communication link in todays advanced communication systems and play a significant role in this process. Microstrip patch antennas are one of the most common antennas used in wireless communication systems today. It is a big step forward when microstrip patch antennas are added to wireless communication systems [20].

With each succeeding generation of wireless technology, there has been an expansion in the range of services that can be made available. Some of the services made available by the internet of things (IoT), for instance, make communication much simpler by providing increased bandwidth, faster connections, and increased security measures. Analog systems, like those used in the first generation (1G), have been replaced by digital systems, like those used in the second generation (2G). The third generation (3G), added new features like global roaming and wideband bandwidth. It made it feasible for users to access applications such as TV and video.

The sector's growth led to the creation of fourth-generation (4G) technology, which improved video calling, mobile TV, and video broadcasting services. The fact that we need 5G technology directly results from how far the wireless industry has come in terms of performance. It can provide technologies with more power than earlier generations were able to. With the help of a new technology called 5G, robots can do more jobs. Devices connected to the IoT provide medical treatment remotely. The microstrip patch antenna element is a great candidate for the 5G antenna role [30]. Microstrip patch antennas are becoming increasingly important in building advanced wireless communication networks. The main reason for this is that more and more people want to use different kinds of wireless applications. Because there are a variety of applications for wireless technology, researchers and scientists have been focusing their efforts on this area [31]. In this section, different international journals and conference papers about 28 GHz have been talked about, which has been used in various wireless applications.

Faisal *et al.* [13], describe a 28 GHz microstrip square patch antenna with a single band is suggested. This paper has low return loss, high gain, improved efficiency, and increased bandwidth, the proposed antenna are well-suited for 5G wireless communication. By utilizing an aired substrate, the antenna's gain can be enhanced. The proposed antenna design can get a very low return loss of -57 dB, which lets it send out a lot of power for 5G communication. Rana and Smieee [15], introduce a microstrip patch antenna tuned to 28 GHz and working at that frequency is looked at and modeled for use in possible 5G communication systems. Through the simulation, the return loss, gain, radiation efficiency, and sidelobe level could be found. Because of this, it can be a strong contender for 5G wireless technology.

Didi *et al.* [32], discuss the study and design of a microstrip patch antenna with a rectangular-shaped slot that works at 28 GHz for wireless applications of the 5G. The antenna is fed using the microstrip line approach. This slot was designed to make improvements to the overall performance of antennas. Consequently, this antenna will fulfill the requirements of 5G wireless communication applications. Tyokighir *et al.* [33], describes how to build and plan fixed wireless access connections in an urban environment using 5G technology in a multi-user urban scenario. Even though the antennas used had a high gain, it was found that the 28 GHz carrier frequency did not work with the connections. The results of this study show how easy it is for route loss to cause problems with high 5G carrier frequencies.

This research, Nahas [34] aims to improve the antenna's gain and other radiation properties. This will be done by putting different kinds of slots into a single rectangular patch, which is how most other 5G antennas are made. The proposed antenna possesses higher gain and directivity, as well as very good VSWR and efficiency, in addition to a bandwidth that is reasonably large and sufficient for the two resonance frequencies that were taken into consideration. Ezzulddin *et al.* [35], shows how to build a single rectangular microstrip antenna (RMPA) that can work at 28 GHz, uses a reliable material for the conductor patch, and has the smallest patch dimensions possible. This antenna will be suitable for 5G communication systems. Bandwidth, return loss, gain, and voltage standing wave ratio are what the optimum patch parameter values of the antenna, which works at 28 GHz, provide, correspondingly.

According to research Ezzulddin *et al.* [36], looks more closely at how finite integration techniques (FIT) and the finite element method (FEM) can evaluate different microstrip antennas, such as rectangular, circular, and triangular patches. This paper describes and analysis of the microstrip antenna parameters such as gain, bandwidth, VSWR, return loss and radiation pattern when the antenna was operating at 28 GHz. Aside from that, the antenna suggested is small, making it easy to add to the 5G wireless communication system. In addition, the antennas nonetheless deliver outstanding radiation performance despite their low-profile configuration by their respective bandwidth, gain, and directivity.

According to research Rahman and Hasan [37], aims to make an equilateral triangular microstrip patch antenna (ETMPA) that works at 28 GHz and can be used in 5G technologies. The results show the return loss, VSWR, efficiency, directivity, gain, and bandwidth, based on the specifications provided above. Finally, the proposed antenna design has the advantage of size reduction compared to most other works, and it is one of the 5G technology requirements. Ameen *et al.* [38], talk about a Vivaldi antenna system that works at 28 GHz and has a switched beam of 4 Vivaldi antennas for communication between cars. The antenna has a central frequency of 28 GHz and an operating bandwidth of 1.463 GHz, and it is designed to function at both of these frequencies.

Bagheri *et al.* [39], showed how well a phased array with 16 by 16 elements that work at 28 GHz and is made for 5G applications works. The proposed architecture uses antenna elements based on a gap waveguide to make design easier and reduce losses in the front of the array. As a result, the phased-array system design has been described as an excellent contender for a compact deployment in practical 5G systems that require beamforming with high output power while simultaneously decreasing the complexity of manufacture. For 5G applications that work at 28 GHz [40], a rectangular patch antenna fed by a wideband microstrip line has been suggested. At this middle stage, a parasitic element in the shape of a star has been used to improve the antenna's gain. But the antenna's high gain can be kept by optimizing not only the ground plane but also the size and position of the cutting edge. The proposed antenna operates in the band at a frequency of 28.201 GHz.

Mahbub *et al.* [41], a rectangular microstrip patch antenna to meet the requirements of future 5G communication systems, which call for better gain and efficiency. The suggested model has both a return loss that is easier to deal with and a strong efficiency. This particular instance used the operating frequency of 28.5 GHz, also known as the Ka-band, which is one of the most important frequency bands for 5G communication. It is improved gain, directivity, efficiency and also reduces return loss, VSWR. Considering all of these things, the antenna that was built might soon be ready to use with 5G communication technology. Pant *et al.* [42], presents an antenna array that has a tapering patches and feeds with a bending transmission line between patches. This antenna was made for 5G wireless communications in the 28 GHz band. By adding a tapered array and bending transmission lines between the patches, the antenna's gain, ability to send out signals over a wide area, and ability to receive signals can all be improved. As a possible use the proposed antenna could be used in 5G wireless communication systems.

Teresa and Umamaheswari [43], designed microstrip antennas to operate at 28 GHz for 5G applications. It has been decided that antennas for 5G networks should work at a frequency of 28 GHz. Analyses and comparisons are made about the performances of the antennas in terms of return loss, bandwidth, efficiency, gain, and directivity. The bandwidth can be increased compared to the previous design because more slots have been added to the layout. The proposed designs are modeled with a high-frequency structure simulator. Ahmad *et al.* [44], proposed a low-profile antenna design in the shape of an umbrella that operates at 28 GHz has both high gain and great efficiency. The high gain and efficiency are achieved without using sophisticated methods to accomplish these goals. The proposed design was declared suitable for mm-wave 5G communication due to it is high gain and high efficiency of steady multidirectional radiation patterns, which are the essential performance metrics it attained.

Przesmycki *et al.* [45], shows an innovative way to design a broadband microstrip antenna that can be used in 5G systems. The central frequency of the proposed antenna is 28 GHz, and it can work in the frequency band for local multipoint distribution service (LMDS). The antenna in the article has a low reflection coefficient, a high energy gain, a wide operating band, and high energy efficiency, among other things. Because of its high throughput, the antenna shown would be an excellent choice for 5G mobile communication.

Goyal and Modani [46], describes a compact planar inset-fed microstrip antenna for use in 5G wireless systems operating at millimetre wave frequencies (28 GHz). It was possible to get a plot of simulated return loss, a field of simulated far-field radiation, and a story of affected polar plot gain. The results of the simulation met the requirements of 3GPP release 15, which said that 5G wireless applications needed to work in the 28 GHz frequency band. The simulation results show a return loss, a gain, and a VSWR, all of which show that the antenna reflects very little at this frequency.

Kaeib *et al.* [47], shows the radiator of a typical rectangular microstrip antenna and how adding slots can change that antenna. This results in a small slotted microstrip antenna with a straightforward construction that is effective for 5G applications at 28 GHz. The proposed slotted antenna's radiation pattern is more focused than regular microstrip antennas. This is because the impedance bandwidth and peak gain are both more considerable. So, the proposed slotted antenna can work well in the required band (27.5−29.5 GHz) and be used correctly for the 5G mobile communication system.

Jebabli *et al.* [48], describes an impedance-matching enhancement to a 1×4 rectangular microstrip antenna array designed for 5G applications in the Ka-band. Several ways to match impedance are compared, such as a quarter-wave transformer, an open or short-circuited length of transmission line (called a "stub"), and smooth shapes made in the low corners of each antenna. At 28 GHz, the input reflection coefficient, gain, and bandwidth are all very good. Ayalew and Asmare [49], shows two miniature versions of a rectangular microstrip patch antenna (RMSPA) with many slots that can be used in 5G mobile communication applications that need a lot of bandwidth. The radiating elements of the proposed antennas change depending on how the places in the slots are set up. The rate at which the air absorbs electromagnetic waves is low at the resonant frequency of 28 GHz, which could be used in 5G applications. Also, the return loss, VSWR, and gain of the antennas suggested are better than what has already been published.

Soti and Chakravarti [50], suggested that millimetre-wave 5G mobile applications use a microstrip patch antenna with a rectangular form that would operate in the 28 GHz frequency spectrum. The suggested antenna has lower return loss, a good bandwidth and standard VSWR. The results of testing the antenna show that it works well in all applications of the new 5G of wireless communications. Park *et al.* [51], a novel combined beam antenna that operates on a frequency band of 28 GHz could be used for 5G communications. This antenna would provide radiation that is tilted on an elevation plane. The antenna's gain in the elevation plane is increased even further by the aperture. Lastly, getting a reasonably high antenna gain is possible even with a large beam that spreads across an azimuthal plane by making the constructive interference between the patches and the gap as good as possible.

Arrouch *et al.* [52], a new, high-gain, rectangular patch antenna with parasitic patch mushrooms is proposed for future 5G communication networks. This antenna has a significant gain and can operate across a broad frequency range. While putting two square DGS on the ground plane increases the bandwidth, parasitic patches on the edges of the main patch increase the gain. In addition, the gain can be increased by using parasitic patches. Or this reason, the proposed antenna is a strong contender for use in 5G applications. Churkin *et al.* [53], describes two microstrip antennas built on a Rogers RT/Duroid 5880 substrate and operating in the 28 GHz band. Both antennas feature radiation patterns shaped like fans, and both are effective at covering wide-angle sectors by communication base stations, regardless of whether the scene takes place inside or outside. The tests showed that the antenna worked well so that it could be used in various communication devices. Najafabadi *et al.* [54], talk about how to design, make, and measure a two-layer, 2×10, elliptic, microstrip series-fed antenna array that works at 28 GHz for 5G application. A branch line coupler made a feeding network for three beams. The dimensions of the 2×10 antenna array, including the coupler, on a Rogers RO4003 substrate, were 80×40×203 mm^3. This design is suitable for use in 5G mobile applications because it costs less and takes up less space.

Lee *et al.* [55], proposes a phased array antenna for the 5G, operating at 28 gigahertz and featuring air-hole slots for increasing beam width. The suggested antenna comprises eight dipoles placed on the ground that is the size of a mobile device. The suggested antenna works very well and has a high-pass bandwidth that has been measured to go up to 219 degrees in the elevation plane and 45 degrees in the azimuth plane. The suggested antenna provides superior hemispheric beam coverage for 5G mobile handset devices and has the potential to facilitate cost-effective mass manufacturing. Razak and Shah [56], presents the antennas for 5G mobile communication at 28 GHz. The simulation showed that the gain and directivity of the microstrip feed line and the inset feed line of the rectangular microstrip patch antenna goes up from a single-element to a four-element array antenna. This adds to the evidence that array antennas, which can produce high gains and directivity while avoiding the problem of millimetre-significant waves' free-space path loss, shrink in size as the number of components in the antenna increases when compared to the size of an antenna with a microstrip feed line. The proposed antenna in this work can be used for 5G mobile communications because they work well with the technology.

According to research Colaco and Lohani [57], made a microstrip patch antenna for high-quality online education and other 5G uses. After simulations, the scientists discovered that the antenna had a decent return loss of 33.4 dB, a reasonable bandwidth of 3.56 GHz, a VSWR of less than 2, a high gain of 10 dB, and a radiation efficiency of 99.5%. During the constant lockdowns around the world, this proposed design has some advantages. According to research Awan *et al.* [58], proposes a printed antenna that is both compact and wideband for 5G communication systems that use millimetre waves. The proposed antenna is likely to be considered for use in the next generation of communication systems because it is small, has a wide frequency range, and has a good gain. Nataraj and Prabha [59], different structured patch designs for microstrip antennas are compared to improve their overall performance for millimeter-wave 5G applications across the frequency spectrum. This work suggests three types of architecture for use at 28 GHz: rectangular, circular, and triangular. The size of the microstrip patch is changed so that it can resonate at 28 GHz, and the simulation results are looked at.

5. ANALYSIS THE PREVIOUSLY PUBLISHED WORKS

Microstrip patch antenna (MSA) is one of the most popular antenna shapes because of it is ease of manufacture and various applications in wireless communication. They are highly handy nowadays because they are directly printed on circuit boards. Microstrip patch antennas are well known for their performance, durability, lightweight design, and applications in numerous industries, for example, medical equipment, satellites, and even military systems such as rockets, aeroplanes, and missiles. Microstrip antennas are popular in all industries and areas, and currently, their low cost to the substrate and manufacturing are both developing economically [60]. The use of antennas is essential to the operation of any electronic communication system. Because different applications have different needs, different types of antennas have been made. To have wireless communication in the modern world, you need to build an antenna that can work on many different frequency bands while remaining small. A microstrip patch antenna fulfills this function. In light of this, several different ways to design antennas are looked at in terms of their design processes and the best performance they offer to meet the needs of wireless communication systems. This research examines how microstrip antennas can be used in different situations. For wireless communication, a new area of research is the building of microstrip patch antennas.

In this section, different types of 28 GHz microstrip patch antennas have been analyzed. Different substrate materials are used to make these antennas with different dielectric permittivity (ε). Also, different antenna parameters like return loss, VSWR, gain, directivity, efficiency, surface current, radiation pattern, and bandwidth, have been pointed out. It has also been found that the defective ground structure method makes patch antennas better in terms of gain, directivity, efficiency, and bandwidth while reducing their size, return loss and VSWR. These antennas can be of various shapes and are used in wireless applications. At a frequency of 28 GHz, Table 1 shows all the values for dielectric permittivity, return loss, gain, directivity, VSWR, efficiency, and bandwidth.

Table 1. Compare return loss, directivity gain, and bandwidth previous published works

Ref	Operating Frequency (GHz)	Dielectricity permittivity (ε)	Return loss (dB)	VSWR	Gain (dB)	Directivity (dBi)	Efficiency (%)	Bandwidth
[13]	28	1	-57	1.0027	10.3	10.6	97	-
[15]	28	2.2	-38.34	1.0244	8.198	-	77	3.46 GHz
[32]	28	2.2	-20.95	1.197	7.5	7.6	99.83	1.06 GHz
[34]	28	-	-25.45		11.26	11.8	95.42	1.10 GHz
[35]	28	2.2	-45.23	1.01	6.72	-	-	0.770 GHz
[36]	28	-	-	-	6	7	85.71	900 MHz
[38]	28	2.2	-	-	9.78	-	-	1.463 GHz
[40]	28	2.2	-31.67	1.05	8.39	9.16	84.5	2.567 GHz
[41]	28.5	-	-48.30	1.007	7.425	8.141	91.16	1.2G Hz
[42]	28	-	-50.35	≤ 2	17.9	-	93.36	1.0 GHz
[43]	28	4.4	-27.79	1.08	6.59	7.45	82.08	2.62 GHz
[44]	28	2.2	-	1.333	7.88	-	92.2	0.445 GHz
[45]	28	2.2	-22.51	-	5.06	-	-	5.57 GHz
[46]	28	-	-18.25	1.278	6.72	-	-	1.10 GHz
[47]	28	4.4	-39.37	1.022	6.37	6.99	86.73	2.48 GHz
[48]	28	2.2	-75	-	13	-	-	-
[50]	28.1	4.4	-17.94	-	-	-	-	3.1 GHz
[51]	28	2.2	-	-	7.41	-	-	-
[52]	28	2.2	-51	1.005	8.04	-	80.6	15.20 GHz
[56]	28	2.2	-40.40		8.0631	8.463	95.27	-
			-55.63		10.86	11.49	94.51	-
[58]	28	3.55	-22	-	-	5.62	87	6.4 GHz
[61]	28	2.2	-35	-	9.24	-	>77	2.10 GHz
[62]	28.1	-	-19.3	1.244	7.02	7.69	91.28	0.9 GHz
[63]	28	3	-34.5	-	6.6	-	-	1.23 GHz
[64]	28	2.2	-40	-	7.6	-	85.6	-
[65]	28	3.66	-	-	6.12	-	95	-
[66]	28	2.2	-14.15	1.48	7.2	-	-	-
[67]	28	2.2	Less than -10	-	15.4	-	-	500 MHz
[68]	28	3.55	-	-	11.8	13.1	83.05	2.06 GHz
[69]	28	2.2	-16.12	-	8.74	-	-	2.817 GHz

6. CONCLUSION

This article discusses new, innovative microstrip patch antennas that work at a frequency of 28 GHz and use different substrate materials and shapes. In addition to that, these antennas had dynamic relative permittivity. According to the simulation's findings, these antennas will have a high directivity gain, the lowest return loss, a broad bandwidth, and high radiation efficiency. Additionally, they will be able to work on both two and three bands at the same time. These studies have been used in many different areas, such as wireless communications, biomedical, machine learning, wireless power transmission, the IoT, artificial intelligence (AI), and many more. The most common way to use microstrip patch antennas is in wireless communication systems like 5G. In addition to ADS, simulations are run with CST, HFSS, MATLAB, and FEKO to get the results.

REFERENCES

[1] M. T. Islam, N. Misran, M. N. Shakib, and B. Yatim, "Stacked multiple slot microstrip patch antenna for wireless communication system," in *Proceedings of ICECE 2008-5th International Conference on Electrical and Computer Engineering*, 2008, pp. 783–786, doi: 10.1109/ICECE.2008.4769316.

[2] W. S. Abdulrab, M. R. Islam, and M. H. Habaebi, "Design of rectangular microstrip patch antenna using stepped cut at four corners for broadband/multiband application," *ARPN Journal of Engineering and Applied Sciences*, vol. 10, no. 22, pp. 17265–17269, 2015.

[3] K. S. Muttair, O. A. Shareef, A. M. A. Sabaawi, and M. F. Mosleh, "Design of multiple-input and multiple-output antenna for modern wireless applications," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 20, no. 1, pp. 34–42, Feb. 2022, doi: 10.12928/TELKOMNIKA.v20i1.19355.

[4] A. Kumar and N. Kumar, "Design of microstrip patch antenna for high gain & directivity at 3.5 GHz by simulation studies using ADS," *International Journal of Engineering Trends and Technology*, vol. 55, no. 1, pp. 1–3, Jan. 2018, doi: 10.14445/22315381/ijett-v55p201.

[5] M. S. Rana, S. Hossain, S. B. Rana, and M. M. Rahman, "Microstrip patch antennas for various applications: a review," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 3, pp. 1511–1519, Mar. 2023, doi: 10.11591/ijeecs.v29.i3.pp1511-1519.

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

[7] R. K. Bajpai, R. Paulus, A. Singh, and M. Aneesh, "Review: dual band microstrip antennas for wireless applications," *International Journal of Advances in Applied Sciences*, vol. 7, no. 2, Jun. 2018, doi: 10.11591/ijaas.v7.i2.pp143-151.

[8] S. M. Shamim, U. S. Dina, N. Arafin, and S. Sultana, "Design of efficient 37 GHz millimeter wave microstrip patch antenna for 5G mobile application," *Plasmonics*, vol. 16, no. 4, pp. 1417–1425, Aug. 2021, doi: 10.1007/s11468-021-01412-x.

[9] A. El Fatimi, S. Bri, and A. Saadi, "Reconfigurable ultra wideband to narrowband antenna for cognitive radio applications using PIN diode," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 18, no. 6, pp. 2807–2814, Dec. 2020, doi: 10.12928/TELKOMNIKA.v18i6.16242.

[10] P. K. Malik, S. Padmanaban, and J. B. Holm-Nielsen, *Microstrip antenna design for wireless applications*. 2021.

[11] R. Tiwari, R. Sharma, and R. Dubey, "Microstrip patch antenna array design anaylsis for 5G communication applications," *Smart Moves Journal Ijoscience*, vol. 6, no. 5, pp. 1–5, May 2020, doi: 10.24113/ijoscience.v6i5.287.

[12] M. S. Rana, B. K. Sen, M. T. Al Mamun, S. I. Sheikh, M. S. Mahmud, and M. M. Rahman, "Design of S-band microstrip patch antenna for wireless communication systems operating at 2.45GHz," in *2022 13th International Conference on Computing Communication and Networking Technologies, ICCCNT 2022*, Oct. 2022, pp. 1–6, doi: 10.1109/ICCCNT54827.2022.9984490.

[13] 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.

[14] T. S. Bird, "Definition and misuse of return loss," *IEEE Antennas and Propagation Magazine*, vol. 51, no. 2, pp. 166–167, Apr. 2009, doi: 10.1109/MAP.2009.5162049.

[15] M. S. Rana and M. M. R. Smieee, "Design and analysis of microstrip patch antenna for 5G wireless communication systems," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 6, pp. 3329–3337, Dec. 2022, doi: 10.11591/eei.v11i6.3955.

[16] N. H. M. Radi, M. M. Ismail, Z. Zakaria, J. A. Razak, and S. N. I. Abdullah, "Development and design of wearable textile antenna on various fabric substrate for unlicensed ultra-wideband applications," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 20, no. 6, pp. 1181–1188, Dec. 2022, doi: 10.12928/TELKOMNIKA.v20i6.23356.

[17] A. Elrashidi, K. Elleithy, and H. Bajwa, "Input impedance, VSWR and return loss of a conformal microstrip printed antenna for TM01 mode using two different substrates," *International Journal of Networks and Communications*, vol. 2, no. 2, pp. 13–19, Aug. 2012, doi: 10.5923/j.ijnc.20120202.03.

[18] S. I. Tous, "Saber Izadpanah Tous," *Voltage Standing Wave Ratio, Department of Electrical Engineering, Mashhad*, 2010.

[19] S. Rana and M. Rahman, "Study of microstrip patch antenna for wireless communication system," in *2022 International Conference for Advancement in Technology, ICONAT 2022*, Jan. 2022, pp. 1–4, doi: 10.1109/ICONAT53423.2022.9726110.

[20] V. Midasala and P. Siddaiah, "Microstrip patch antenna array design to improve better gains," *Procedia Computer Science*, vol. 85, pp. 401–409, 2016, doi: 10.1016/j.procs.2016.05.181.

[21] S. Singh, N. Agarwal, N. Nitin, and A. K. Jaiswal, "Design consideration of microstrip patch antenna," *International Journal of Electronics and Computer Science Engineering*, vol. 2, no. 1, pp. 306–316, 2012.

[22] W. L. Stutzman, "Estimating directivity and gain of antennas," *IEEE Antennas and Propagation Magazine*, vol. 40, no. 4, pp. 7–11, 1998, doi: 10.1109/74.730532.

[23] N. Kaur, M. Kumar, and J. Singh, "Design of miniaturized stair case fractal geometry based planar monopole antenna for multiband wireless communication applications," *International Journal of Mechanical Engineering*, vol. 7, pp. 974–5823, 2022.

[24] W. A. Godaymi, A.-K. A. A. Mohammed, and Z. A. Ahmed, "Determination of surface currents on circular microstrip antennas," *Journal of electromagnetic engineering and science*, vol. 12, no. 4, pp. 260–270, Dec. 2012, doi: 10.5515/jkiees.2012.12.4.260.

[25] M. Abirami and A. Vimala, "A review of various antenna design methods for cognitive radio application," in *Proceedings of 2017 4th International Conference on Electronics and Communication Systems, ICECS 2017*, Feb. 2017, pp. 117–120, doi: 10.1109/ECS.2017.8067850.

[26] Chandan and B. S. Rai, "Bandwidth enhancement of wang shape microstrip patch antenna for wireless system," in *Proceedings-2014 4th International Conference on Communication Systems and Network Technologies, CSNT 2014*, Apr. 2014, pp. 11–15, doi: 10.1109/CSNT.2014.11.

[27] A. Mahabub, M. M. Rahman, M. Al-Amin, M. S. Rahman, and M. M. Rana, "Design of a multiband patch antenna for 5G communication systems," *Open Journal of Antennas and Propagation*, vol. 6, no. 1, pp. 1–14, 2018, doi: 10.4236/ojapr.2018.61001.

[28] S. K. Ibrahim and Z. T. Jebur, "A high gain compact rectangular patch antenna for 5G applications," in *International Conference on Communication and Information Technology, ICICT 2021*, Jun. 2021, pp. 156–160, doi: 10.1109/ICICT52195.2021.9568415.

[29] G. P. Mishra, M. S. Maharana, S. Modak, and B. B. Mangaraj, "Study of sierpinski fractal antenna and its array with different patch geometries for short wave ka band wireless applications," *Procedia Computer Science*, vol. 115, pp. 123–134, 2017, doi: 10.1016/j.procs.2017.09.085.

[30] M. Sowe, D. B. O. Konditi, and P. K. Langat, "A compact high-gain microstrip patch antenna with improved bandwidth for 5G

applications," *International Journal of Electrical and Electronics Research*, vol. 10, no. 2, pp. 196–201, Jun. 2022, doi: 10.37391/IJEER.100225.
[31] 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*, vol. 10, no. 4, pp. 945–954, Dec. 2022, doi: 10.52549/ijeei.v10i4.4141.
[32] S. E. Didi, I. Halkhams, M. Fattah, Y. Balboul, S. Mazer, and M. El Bekkali, "Design of a microstrip antenna patch with a rectangular slot for 5G applications operating at 28 GHz," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 20, no. 3, pp. 527–536, Jun. 2022, doi: 10.12928/TELKOMNIKA.v20i3.23159.
[33] S. S. Tyokighir, J. M. Mom, K. E. Ukhurebor, and G. A. Igwue, "Design and planning of a 5G fixed wireless network," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 3, pp. 1523–1527, Jun. 2023, doi: 10.11591/eei.v12i3.4901.
[34] M. Nahas, "A super high gain L-slotted microstrip patch antenna For 5G mobile systems operating at 26 and 28 GHz," *Engineering, Technology and Applied Science Research*, vol. 12, no. 1, pp. 8053–8057, 2022, doi: 10.48084/etasr.4657.
[35] S. K. Ezzulddin, S. O. Hasan, and M. M. Ameen, "Optimization of rectangular microstrip antenna patch parameters to operate with high radiation performances for 5G applications," in *AIP Conference Proceedings*, 2022, vol. 2386, doi: 10.1063/5.0066800.
[36] 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, Apr. 2022, doi: 10.1016/j.simpat.2022.102497.
[37] B. A. Rahman and S. O. Hasan, "Simulation design of low-profile equilateral triangle microstrip patch antenna operating at 28 GHz," *International Journal on Communications Antenna and Propagation*, vol. 12, no. 2, pp. 74–82, Apr. 2022, doi: 10.15866/irecap.v12i2.21964.
[38] A. M. Ameen, M. I. Ahmed, H. Elsadek, and W. R. Anis, "28 GHz switched beam vivaldi antenna system for V2V communication in 5G applications," *Radioengineering*, vol. 31, no. 1, pp. 32–38, Apr. 2022, doi: 10.13164/RE.2022.0032.
[39] A. Bagheri *et al.*, "A 16×16 45° slant-polarized gapwaveguide phased array with 65-dBm EIRP at 28 GHz," *IEEE Transactions on Antennas and Propagation*, vol. 71, no. 2, pp. 1319–1329, 2023, doi: 10.1109/TAP.2022.3227718.
[40] L. C. Paul, M. H. Ali, N. Sarker, M. Z. Mahmud, R. Azim, and M. T. Islam, "A wideband rectangular microstrip patch antenna with partial ground plane for 5G applications," in *2021 Joint 10th International Conference on Informatics, Electronics and Vision, ICIEV 2021 and 2021 5th International Conference on Imaging, Vision and Pattern Recognition, icIVPR 2021*, Aug. 2021, pp. 1–6, doi: 10.1109/ICIEVICIVPR52578.2021.9564160.
[41] F. Mahbub, R. Islam, S. A. K. Al-Nahiun, S. B. Akash, R. R. Hasan, and M. A. Rahman, "A single-band 28.5GHz rectangular microstrip patch antenna for 5G communications technology," in *2021 IEEE 11th Annual Computing and Communication Workshop and Conference, CCWC 2021*, Jan. 2021, pp. 1151–1156, doi: 10.1109/CCWC51732.2021.9376047.
[42] M. Pant, L. Malviya, and V. Choudhary, "Gain and bandwidth enhancement of 28 GHz tapered feed antenna array," in *2020 11th International Conference on Computing, Communication and Networking Technologies, ICCCNT 2020*, Jul. 2020, pp. 1–4, doi: 10.1109/ICCCNT49239.2020.9225502.
[43] P. M. Teresa and G. Umamaheswari, "Compact slotted microstrip antenna for 5G applications operating at 28 GHz," *IETE Journal of Research*, vol. 68, no. 5, pp. 3778–3785, Sep. 2022, doi: 10.1080/03772063.2020.1779620.
[44] I. Ahmad, S. Houjun, Q. Ali, and A. Samad, "Design of Umbrella shape single element patch antenna with high gain and high efficiency for 5G wireless communication in 28 GHz," in *Proceedings of 2020 17th International Bhurban Conference on Applied Sciences and Technology, IBCAST 2020*, Jan. 2020, pp. 710–713, doi: 10.1109/IBCAST47879.2020.9044577.
[45] R. Przesmycki, M. Bugaj, and L. Nowosielski, "Broadband microstrip antenna for 5g wireless systems operating at 28 ghz," *Electronics (Switzerland)*, vol. 10, no. 1, pp. 1–19, Dec. 2021, doi: 10.3390/electronics10010001.
[46] R. K. Goyal and U. S. Modani, "A compact microstrip patch antenna at 28 GHz for 5G wireless applications," in *3rd International Conference and Workshops on Recent Advances and Innovations in Engineering, ICRAIE 2018*, Nov. 2018, pp. 1–2, doi: 10.1109/ICRAIE.2018.8710417.
[47] A. F. Kaeib, N. M. Shebani, and A. R. Zarek, "Design and analysis of a slotted microstrip antenna for 5G communication networks at 28 GHz," in *19th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering, STA 2019*, Mar. 2019, pp. 648–653, doi: 10.1109/STA.2019.8717292.
[48] E. Jebabli, M. Hayouni, and F. Choubani, "Impedance matching enhancement of a microstrip antenna array designed for Ka-band 5G applications," in *2021 International Wireless Communications and Mobile Computing, IWCMC 2021*, Jun. 2021, pp. 1254–1258, doi: 10.1109/IWCMC51323.2021.9498825.
[49] L. G. Ayalew and F. M. Asmare, "Design and analysis of compact slotted rectangular microstrip patch antenna for 5G communication systems operating at 28 GHz," in *2022 IEEE 7th International conference for Convergence in Technology, I2CT 2022*, Apr. 2022, pp. 1–6, doi: 10.1109/I2CT54291.2022.9824399.
[50] S. Soti and P. K. Chakravarti, "A compact patch antenna with DGS for 28GHz 5G millimetre band applications," in *2022 IEEE 7th International conference for Convergence in Technology, I2CT 2022*, Apr. 2022, pp. 1–4, doi: 10.1109/I2CT54291.2022.9824559.
[51] J. S. Park, J. B. Ko, H. K. Kwon, B. S. Kang, B. Park, and D. Kim, "A tilted combined beam antenna for 5G communications using a 28-GHz band," *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 1685–1688, 2016, doi: 10.1109/LAWP.2016.2523514.
[52] T. El Arrouch, N. E. A. El Idrissi, and A. El Ansari, "Microstrip patch antenna using a parasitic mushroom for 5G application at 28GHz," in *Proceedings-2022 9th International Conference on Wireless Networks and Mobile Communications, WINCOM 2022*, Oct. 2022, pp. 1–6, doi: 10.1109/WINCOM55661.2022.9966479.
[53] S. Churkin, A. Mozharovskiy, A. Artemenko, and R. Maslennikov, "Microstrip patch antenna arrays with fan-shaped 90 and 45-degree wide radiation patterns for 28 GHz MIMO applications," 2018, doi: 10.1049/cp.2018.1204.
[54] A. M. A. Najafabadi, F. A. Ghani, and I. Tekin, "A 28 GHz beam steerable elliptic microstrip array antenna for 5G applications," in *2022 16th European Conference on Antennas and Propagation, EuCAP 2022*, Mar. 2022, pp. 1–4, doi: 10.23919/eucap53622.2022.9769468.
[55] H. Lee, S. Kim, and J. Choi, "A 28 GHz 5G phased array antenna with air-hole slots for beam width enhancement," *Applied Sciences (Switzerland)*, vol. 9, no. 20, Oct. 2019, doi: 10.3390/app9204204.
[56] N. S. Razak and S. M. Shah, "Antenna for 5G mobile communication at 28 GHz," *Journal of Electronic Voltage and Application*, vol. 3, no. 1, Jun. 2022, doi: 10.30880/jeva.2022.03.01.003.
[57] J. Colaco and R. Lohani, "Design and implementation of microstrip patch antenna for 5G applications," in *2020 5th International Conference on Communication and Electronics Systems (ICCES)*, Jun. 2020, pp. 682–685, doi: 10.1109/icces48766.2020.9137921.

[58] W. A. Awan, S. I. Naqvi, A. H. Naqvi, S. M. Abbas, A. Zaidi, and N. Hussain, "Design and characterization of wideband printed antenna based on DGS for 28 GHz 5G applications," *Journal of Electromagnetic Engineering and Science*, vol. 21, no. 3, pp. 177–183, Jul. 2021, doi: 10.26866/jees.2021.3.r.24.
[59] B. Nataraj and K. R. Prabha, "Analysis of various microstrip patch antenna designs for 5G applications," in *2022 1st International Conference on Electrical, Electronics, Information and Communication Technologies, ICEEICT 2022*, Feb. 2022, pp. 1–4, doi: 10.1109/ICEEICT53079.2022.9768642.
[60] P. Kumar, R. Gangwar, and N. K. Yadav, "Microstrip patch antenna," *International Journal for Research in Applied Science and Engineering Technology*, vol. 10, no. 5, pp. 5303–5307, May 2022, doi: 10.22214/ijraset.2022.42690.
[61] S. Sharma and M. Arora, "A millimeter wave elliptical slot circular patch MIMO antenna for future 5G mobile communication networks," *Progress In Electromagnetics Research M*, vol. 110, pp. 235–247, 2022, doi: 10.2528/PIERM22041101.
[62] Y. Zhang, J. Y. Deng, M. J. Li, D. Sun, and L. X. Guo, "A MIMO dielectric resonator antenna with improved isolation for 5G mm-wave applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 18, no. 4, pp. 747–751, Apr. 2019, doi: 10.1109/LAWP.2019.2901961.
[63] A. E. Farahat and K. F. A. Hussein, "Dual-band (28/38 GHz) wideband MIMO antenna for 5G mobile applications," *IEEE Access*, vol. 10, pp. 32213–32223, 2022, doi: 10.1109/ACCESS.2022.3160724.
[64] M. I. Khattak, A. Sohail, U. Khan, Z. Ullah, and G. Witjaksono, "Elliptical slot circular patch antenna array with dual band behaviour for future 5G mobile communication networks," *Progress In Electromagnetics Research C*, vol. 89, pp. 133–147, 2019, doi: 10.2528/PIERC18101401.
[65] K. Ullah *et al.*, "Design and analysis of a compact dual-band patch antenna for 5G mmW application," in *2020 14th International Conference on Open Source Systems and Technologies, ICOSST 2020-Proceedings*, Dec. 2020, pp. 1–5, doi: 10.1109/ICOSST51357.2020.9333070.
[66] M. Kavitha, T. D. Kumar, A. Gayathri, and V. Koushick, "28 GHZ printed antenna for 5G communication with improved gain using array," *International Journal of Scientific and Technology Research*, vol. 9, no. 3, pp. 5127–5133, 2020.
[67] A. Omar, S. Al-Saif, M. A. Ashraf, and S. Alshebeili, "Design and analysis of millimeter wave series fed microstrip patch array for next generation wireless communication systems," in *2016 17th International Symposium on Antenna Technology and Applied Electromagnetics, ANTEM 2016*, Jul. 2016, pp. 1–2, doi: 10.1109/ANTEM.2016.7550139.
[68] A. A. Ibrahim, H. Zahra, O. M. Dardeer, N. Hussain, S. M. Abbas, and M. A. Abdelghany, "Slotted antenna array with enhanced radiation characteristics for 5G 28 GHz communications," *Electronics (Switzerland)*, vol. 11, no. 17, Aug. 2022, doi: 10.3390/electronics11172664.
[69] S. Ashraf, J. A. Sheikh, and Z. A. Bhat, "A high gain multi slotted and compact planar microstrip millimeter wave antenna for 5G networks," *Progress In Electromagnetics Research M*, vol. 108, pp. 175–186, 2022, doi: 10.2528/PIERM22010904.

BIOGRAPHIES OF AUTHORS

Md. Sohel Rana a B.Sc. Engineering Degree in Electrical and Electronic Engineering from Prime University (PU), Bangladesh, in 2015. In 2018, he got his first Master of Science (M.Sc.) in Telecommunication Engineering from the University of Information Technology and Sciences (UITS), Bangladesh. He completed his second M.Sc. in Engineering (Master of Science in Engineering in Information Systems Security) from Bangladesh University of Professionals (BUP), Bangladesh, in 2022. He has completed his third M.Sc. in the Department of Electrical and Electronic Engineering at Independent University, Bangladesh (IUB), Bangladesh, in 2023. His research interests include microstrip patch antenna, wireless communication, image processing, renewable energy, solar cell, biomedical engineering, control systems, and power electronics. Mr. Rana has published more than 40 research articles in peer-reviewed journals and international conferences. At present, he is a lecturer and head (in-charge) in the Department of Electrical and Electronic Engineering at the Northern University of Business and Technology Khulna, Khulna, Bangladesh. He can be contacted at email: sohel.rana@uits.edu.bd.

Piyal Mistry is currently in his final year of studies as an undergraduate at the Northern University of Business and Technology in Khulna. He is majoring in the Department of Electrical and Electronic Engineering of the university. The design of antennas, VLSI, wireless communication, and renewable energy are some of his scientific areas of interest. He can be contacted at email: pgpiyalm@gmail.com.

Md. Jahidur Rahaman is currently in his final year undergraduate student at the Northern University of Business and Technology Khulna in the Department of Electrical and Electronic Engineering. His scientific areas of interest include the design of antennas, power system, wireless communication, and renewable energy. He can be contacted at email: jahidur725@gmail.com.

Sahriar Islam Shipon is an undergraduate final-year student at Northern University of Business and Technology Khulna in the Department of Electrical and Electronic Engineering. His research interests are antenna design, renewable energy, and wireless communication. He can be contacted at email: sahriarislam896@gmail.com.

Shake Zion Haider Ovi is a student in the Department of Electrical and Electronic Engineering at the Northern University of Business and Technology in Khulna, where he is in his final year of study as an undergraduate. His scientific interests include antenna design as well as wireless communication and renewable energy. He can be contacted at email: skovi649183@gmail.com.

Md. Masud Rana is a student in the Department of Electrical and Electronic Engineering at the Northern University of Business and Technology in Khulna, where he is in his final year of study as an undergraduate. His scientific interests include antenna design as well as wireless communication and renewable energy. He can be contacted at email: masudranadxn@gmail.com.

Tahasin Ahmed Fahim received the Bachelor of Science in Electrical and Electronic Engineering degree from the Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh in 2016. He also received the Master of Science in Electrical and Electronic Engineering from the same university in 2019. He has been working as lecturer in the Department of Electrical and Electronic Engineering at the Noakhali Science and Technology University, Noakhali, Bangladesh from 2022. He also worked as a faculty member in the Department of Electrical and Electronic Engineering at the Bangladesh Army University of Science and Technology, Saidpur, Bangladesh from 2016 to 2022. He authored and co-authored in 14 papers regarding to his research works. He is a member of IEEE since 2012. He received best paper award in the international IEEE conference in 2019. He can be contacted at email: tahasin.fahim.bd@ieee.org.