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A review of 2.45 GHz microstrip patch antennas for wireless applications

Md. Sohel Rana[1,2,3,4], Tanvir Rahman Rocky[1], Md. Arif Islam[1], Al Mamun[1], Sanjay Kumar Joy[1], Saikat Mondal[1], Md. Toukir Ahmed[5], Md. Hasibul Islam[1,6], Sourav Pal[1], Imran Chowdhury[7], Omar Faruq[8]

[1]Department of Electrical and Electronic Engineering, Northern University of Business and Technology Khulna, Khulna, Bangladesh
[2]Department of Computer Science and Engineering, Bangladesh University of Professionals, Dhaka, Bangladesh
[3]Department of Electrical and Electronic Engineering, Independent University, Bangladesh, Dhaka, Bangladesh
[4]Department of Electrical and Electronic Engineering, Prime University, Dhaka, Bangladesh
[5]Department of Internet of Things and Robotics Engineering, Bangabandhu Sheikh Mujibur Rahman Digital University, Dhaka, Bangladesh
[6]Department of Computer Science and Engineering, Northern University of Business and Technology Khulna, Khulna, Bangladesh
[7]Department of Electrical and Electronic Engineering, Northern University Bangladesh, Dhaka, Bangladesh
[8]Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

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ABSTRACT

Recently, microstrip patch antennas have become popular. Due to their ubiquity, these antennas have more uses every day. In this research paper, a 2.45 GHz microstrip patch antenna has been reviewed and analyzed. Different substrate materials have been used to make these antennas, and their thickness is different. Various antennas are designed based on the application, such as rectangular, square, triangle, ring, donut, and dipole. Other types of software were used to design the antenna, including CST, HFSS, MATLAB, ADS, and FEKO. Microstrip patch antenna design is a relatively new field of study for wireless applications. Several devices are linked to send or receive radio waves using a single antenna. Antennas designed for 2.45 GHz are used in various wireless communication systems, including television broadcasts, microwave ovens, mobile phones, wireless local area network (WLAN), Bluetooth, global positioning system (GPS), and two-way radios. This article looks at the geometric structures of antennas, including their many parameters and materials and the many different shapes they can take. In addition, the substrate materials, the loss tangent, the thickness, the return loss, the bandwidth, the voltage standing wave ratio (VSWR), the gain, and the directivity of previous articles will also be discussed.

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

In the past few decades, there has been an expansion in the number of wireless networks, which has resulted in additional bandwidth to accommodate the massive volumes of data that high-data-rate applications require. Increasing the number of wireless technologies on the radio frequency (RF) spectrum is necessary. These technologies include Bluetooth, WiFi, worldwide interoperability for microwave access (WiMAX), global systems for mobile communication (GSM), satellite, and ultra-wideband (UWB). It is the function of the device that is the critical factor that determines the type of antenna that should be used. It is becoming increasingly common to employ microstrip patch antennas for wireless communication because they are inexpensive, simple to manufacture, lightweight, possess an omnidirectional, two-dimensional field pattern, have flexible feed lines, and are compatible with solid-state equipment. In the 1950s, the inaugural microstrip antenna was made accessible to the general public for the first time. Beginning in the early 1980s, its development rate increased, and it is still strong [1]. It is common practice to use antennas, an essential component of the communications field. A transducer is a device that converts electrical energy into radio signals and radio signals into electrical energy. Put another way, it is a device that turns electrical power into radio signals. The advent of wireless communication technology has made it possible for people who live in areas that are difficult to access to communicate with one another. This technology enables them to send and receive signals at the same time [2].

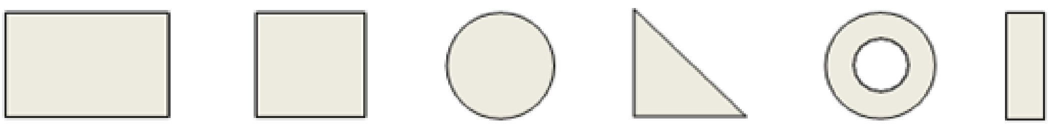
Figures 1 illustrate assembling the microstrip patch antenna structure, Figure 1(a) shows the physical construction of MPA and Figure 1(b) shows the significant parts of the microstrip patch antenna. It has four major parts. These are substrate ground, substrate material, microstrip patch, and feedline. Microstrip patch antenna are constructed from conducting and insulating materials divided into three pieces. These sections are isolated from one another. Each top and bottom layer is made from conductive materials, specifically patch and ground. One of the materials that can be utilized in producing the ground structure layer, also called the bottom structure layer, is copper. On the other hand, the middle layer, which separates the two levels, is constructed out of a dielectric material known as the substrate. Various dielectric materials can be used to build the substrate and the middle layer, including air, FR4, Rogers, and others. A highly conductive substance is produced by copper, which is then utilized in constructing the top layer, referred to as the patch or design layer. When designing an antenna for a particular application, one of the most essential aspects to take into consideration is the selection of materials that will serve as conductors and materials that will serve as insulators at the same time [3]-[4].

Within today's wireless networks, more than five billion devices are required to connect to wireless networks, allowing speech, data, and other applications to function. The amount of data sent and received has increased over several years, resulting in the decreased usefulness of 4G mobile communication technologies [6]. Better wireless transmission technology is required for fifth-generation (5G) mobile communication systems for them to be able to provide higher throughput rates, faster speeds, and lower energy consumption [7]. There are a variety of designs that can be developed for microstrip patch antenna for use in wireless applications. As seen in Figure 2, especially in Figures 2(a)-(f) these shapes include rectangles, squares, circles, triangles, donuts, and dipoles [8].

For organization, the paper is broken up into six sections. In addition to that, the structure of the form is in the following order: first, the introduction is presented in section 1; then, in section 2, it describes the history of microstrip patch antenna; in section 3, a literature review is given; then, in section 4, their parametric investigations are presented; then, in section 5, the analysis and research gap is shown; and finally, in section 6, the conclusion is described.

(a) (b)

Figure 1. Geometry of (a) physical construction and (b) significant parts of microstrip patch antenna [5]



(a) (b) (c) (d) (e) (f)

Figure 2. Different shapes of microstrip patch antenna (a) rectangle, (b) square, (c) circle, (d) triangle, (e) donut, and (f) dipole

2. MICROSTRIP PATCH ANTENNA

In 1935, G.A. Deschamps was the first person to propose the idea of a microstrip antenna; moreover, at the time, the idea received little attention from researchers. Until 1972, researchers like R.E. Munson and J.Q. Howell were the first to construct microstrip antennas due to the development of microwave integration technology and the necessity for low-profile antennas in space technology. Researchers such as R.E. Munson and J.Q. Howell were responsible for creating the first microstrip antennas. Improvements in microwave integration technology and low-power dielectric materials made this possible. 1979 was the year that New Mexico State University played host to the International Conference on Microstrip Antennas. The following year, 1981, the IEEE Antennas and Propagation Journal issued a special issue on microstrip antennas in January. This publication established microstrip antennas as a specialized branch within the subject of antennas [9]. The microstrip antenna is a piece of equipment that can change the form that electrical power takes into that of an electromagnetic wave and vice versa. The applications for wireless communication systems are where they shine the brightest. Multiband and wideband patch antennas will soon require speech, data, video, and other multimedia information to be sent accurately in wireless communications today. However, the most significant drawback of a patch antenna is that it has a narrow bandwidth. This is because surface waves cause losses when a patch antenna is put on a dielectric substrate. It is well known that microstrip patch antennas have a quality that is both long-lasting and easy to apply.

Microstrip patch antennas are used in various applications, including in the medical area, the telecommunications field, and even military hardware, such as rockets, aircraft missiles, and many other types of equipment. They can be used for a wide variety of purposes. A prime candidate meets at least one of the following criteria: mobile and satellite communication, RF identification, interoperability for microwave access, radar application, global positioning system (GPS), and reduced-size microstrip patch antenna for Bluetooth [10]. Figure 3 displays the microstrip antennas in their most basic design. It is constructed using a ground plane on one side and a radiating patch on the other side of a dielectric substrate. The radiating patch is located on one side of the substrate. There are four primary categories into which all microstrip antennas can be placed: i) microstrip patch antenna, ii) microstrip dipoles, iii) printed slot antennas, and iv) microstrip traveling-wave antennas.

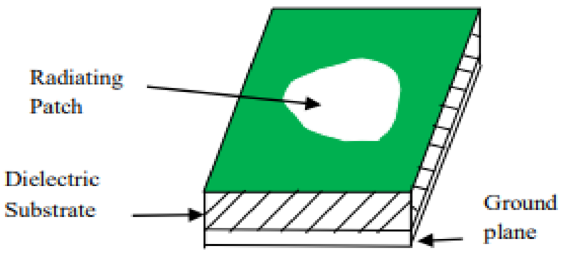


Figure 3. Microstrip antenna configuration

An illustration of the microstrip line-feed patch antenna may be found in Figure 4. This method only requires a conducting strip linked to the patch to build a line feed. This makes it one of the most straightforward methods available. As a result, it could be an extension of the patch itself. In addition, the proximity-coupled microstrip patch antenna is illustrated in Figure 5. Proximity coupling has the largest bandwidth and produces the least unwanted radiation. The patch's width-to-length ratio and the feeding stub's length both play a role in determining the level of control exerted over the match. Its coupling mechanism can be described in terms of how capacitive it is [11].

Several pieces of software can be used to construct microstrip patch antennas. A few examples of software are COMSOL, FEKO, MATLAB, HFSS, ADS, and CST. Most researchers use HFSS and CST software to build antennas among them. A microstrip patch antenna size can be calculated using several different formulas. Some of the more critical governing equations are listed here [12], [13], [14]:

Step 1: the width of the patch:

$$\mathrm{Wp} = \frac{c_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

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

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

Step 3:

$$L_{eff} = \frac{c_o}{2f_r\sqrt{\varepsilon_{reff}}} \quad (3)$$

Step 4: computing the length extension of an antenna

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

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

$$L_P = Leff - 2\Delta L \quad (5)$$

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

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

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

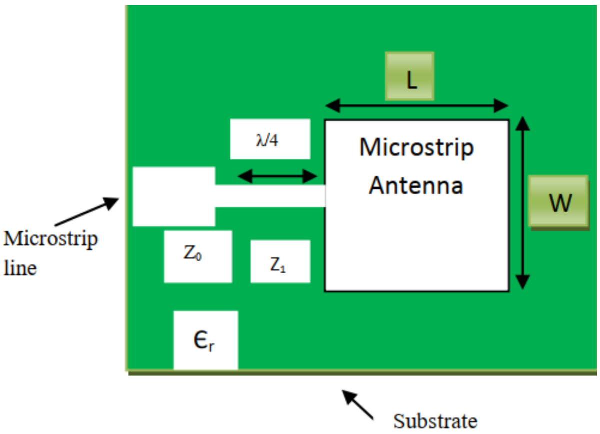


Figure 4. Patch antenna with microstrip line as the feed

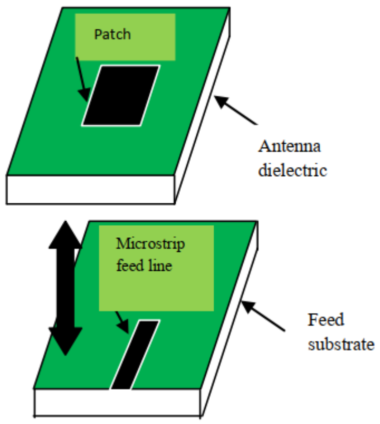


Figure 5. Microstrip patch antenna that is connected by proximity

3. LITERATURE REVIEW

This section will discuss the various uses of microstrip patch antennas. This study will discuss how the authors have used microstrip patch antennas. This antenna has been put to work in several situations until now. The current technology is driving greater demand for the utilization of these antennas. Every day, more and more industries, including wireless communications, medical research, electronics, wireless power transfer (WPT), autonomous vehicles, medical physics, and machine learning, find increasingly valuable applications. Various previously published papers on 2.45 GHz are discussed.

Research by Islam *et al.* [15], suggests a rectangular patch antenna with a partial ground plane (PGP) for use in wireless local area networks (WLAN) inside buildings. The antenna that has been recommended is compatible with various wireless communication protocols. These standards include Bluetooth, WiMAX, radio frequency identification (RFID), S-band, wireless communication services (WCS), and 4G LTE. Research by Loss *et al.* [16], shows a study of the properties of textile materials that can be used to make wearable antennas and a simulation of a textile antenna for energy harvesting in the 2.4 GHz frequency range. The study focuses on the features of textile materials. It is intended for a wearable antenna to become an integral part of the article of clothing, transforming the garment into an interface for communication purposes.

Rahman *et al.* [17], present how a wideband microstrip patch antenna was made for use in the industrial, scientific, and medical (ISM) band at 2.45 GHz and how well it worked. This antenna has a wide bandwidth of 21.67% and a resonance frequency of 2.4 GHz. The suggested antenna's performance is compared to that of several RFID reader antennas that work in the ISM band. Research by Nornikman *et al.* [18], introduces a dual-layer rectangular microstrip patch antenna with an H-slot proposed to reduce return loss and maximize gain for frequencies of 2.4 GHz and 2.45 GHz. The results of both simulations and real-world tests show that this antenna has good radiation behavior in the RFID frequency range. This work was successful in obtaining the frequency, gain, and return loss as well as the radiation pattern at frequencies of 2.4 GHz for the WLAN application and 2.45 GHz for the RFID.

Irene and Mariappan [19], present a circular patch microstrip array antenna in the ISM band, corresponding to the S-band (2-4 GHz). To supply the antenna, an inset-fed microstrip line feed was utilized. The voltage standing wave ratio (VSWR) measurement, as well as the return loss measurement, were both taken with the network analyzer. A pattern measurement setup was used to figure out the radiation pattern. The horn antenna was used as the antenna to be tested. Adami *et al.* [20], discuss a flexible wireless power-harvesting wristband that works at 2.45 GHz and turns 24.3 dBm of RF energy into a net DC output. A system has been built with a fabric antenna, a rectifier on a rigid substrate, a contactless electrical connection between rigid and flexible parts, and power electronics impedance matching. A self-powered boost converter with a quiescent current of 150 nA and matching the effectiveness of more than 95% is required to match the output of the rectenna. At a signal level of -7 dBm, the end-to-end efficiency can reach an optimum of 28.7%. The wristband harvester shows that it is possible to collect net positive energy from a signal that is 7.3 dB lower in level than the current state of the art.

Muhammad and Idris [21], presents to make a rectangular microstrip patch antenna that can be used in global WLAN systems. It also looks at how different antenna parameters affect the antenna's performance, such as its radiation pattern, directivity, gain, bandwidth, VSWR, return loss, and far field. This antenna was intended to be used for applications such as IEEE 802.11 Wi-Fi, IEEE 802.15.1 Bluetooth, IEEE 802.15.4 ZigBee, wireless USB, microwave ovens, codeless phones, and other similar devices. According to Shimu and Ahmed [22], the design, simulation, and performance analysis of a single-element rectangular microstrip patch antenna and a 2x1 patch array is presented in this article for use in the ISM band (2.45 GHz). A patch array with only two elements can improve gain, directivity, and bandwidth. Microstrip line feed is used, CST microwave studio is used to run simulations and the wave and antenna training system is used to measure the antennas that have been made (WATS-2002). Research by Nagabhushana *et al.* [23], shows a microstrip patch antenna with two bands and small slots that could be used in wireless applications. The HFSS is used to analyze the microstrip patch antenna with meandering slots to determine its parameters, such as its return loss, directivity, bandwidth, gain, and VSWR. The antenna provides two helpful resistance bands, which operate efficiently overall. Therefore, the first band is utilized in WLAN, and the second band, WiMAX, uses this frequency.

According to research by Jain *et al.* [24], a microstrip patch antenna in the shape of an E is described as a rectangular patch that contains both a circular and a rectangular slot within the patch. The return loss, vertical standing wave ratio, and bandwidth will be known by putting forward a design for an antenna and feeding it with a coaxial cable in the right place. The primary antenna has built-in e-type slots, and the current setup can immediately meet the needs of several different wireless communication systems. Sediq [25], presents the construction of a coaxial feeding elliptical microstrip patch antenna for a device used in wireless communication. The suggested approach has shown that it can achieve the desired result of a higher gain. As discussed in this paper, applying this method not only increases the antenna gain but also leads to an extension of the 3-dB bandwidth of the antenna as well as other antenna parameters. As a result, the elliptical microstrip patch antenna was developed for use in wireless communication systems that function at 2.45 GHz.

According to Benkhadda [26], the designs, as well as the feeding techniques for a rectangular microstrip antenna, are presented. The proposed rectangular microstrip antenna was made using the transmission line method as a base. In addition, it has been improved using the method of moment. measurements of the reflection coefficient, gain, and bandwidth were used to compare how well the different feeding methods worked. Tawfeeq and Mahmood [27] describe an octagonal ring-shaped multi-slot patch antenna with a single resonant frequency at 2.45 GHz of the ISM band and an omnidirectional pattern based on the Tikrit University logo. The findings demonstrate a gain, an improved return loss, and an omnidirectional radiation pattern that can be utilized to collect RF energy from Wi-Fi and Bluetooth devices.

As part of this research Bharathi *et al*. [28], make a microstrip patch antenna that works at 2.45 GHz and can be used in wireless applications. It has been investigated whether or not there is a correlation between the shape of the suggested microstrip patch antenna and the return loss, VSWR, bandwidth, and radiation pattern of the antenna. Research by Memon *et al.* [29] discusses a textile rectangular ring microstrip patch antenna capable of allowing more water vapor to pass through. To make the breathable textile rectangular ring microstrip patch antenna even better at letting water vapor pass through it, a new technique was used to place several small holes with a diameter of 1 mm in the conductive layers of the antenna. This made the antenna even better at letting water vapor pass through it. At a specific frequency of 2.45 GHz, the antenna was meant to resonate with the bands used in ISM applications.

Research by Güler *et al.* [30] shows how to make a microstrip patch antenna that works well in the ISM environment and has a wide frequency range. The investigation consists of a phase of simulation, a phase of fabrication, and a phase of measurement. The research paper presents four distinct antenna designs, analyzes the results, and concludes that the suggested antenna has a rational bandwidth, return loss, and directivity gain. The suggested antenna is well-suited for use in applications involving the ISM band. Research by Duman *et al.* [31], a rectangular microstrip patch antenna fed from the interior is created with the help of the CST design studio program for this undertaking. This research has four distinct grounding methods, each with five measurements (the first method only has two measures), and each is distinct from its counterpart. It can maintain the required level of radiation while working within the antennas' limits. In addition to determining whether or not the return loss meets the requirements, the VSWR and quality component should be investigated. Research by Devi *et al.* [32], shows a rectangular patch antenna that is meant to work in the 2.45 GHz frequency range used in the ISM sectors. A novel microstrip patch antenna with a short range, low power, and excellent directionality has been developed to enhance the performance of wireless sensor communication applications that run at frequencies of 2.4 GHz and 5.3 GHz.

Research by Hoang *et al.* [33], discusses how to design, simulate, and make microstrip patch antenna arrays for close-range wireless power transfer systems. Different antenna prototypes, some of which operate at 2.45 GHz, have been proposed. The fabricated antenna achieves a directivity of 14.7 dBi, according to the findings of the measurements, and a beamwidth of 23.2 degrees, as measured by 3 dB. It has been determined that the experiment with the WPT technology was a success. Mutlu and Kurnaz [34], show how a rectangular microstrip antenna was built and simulated for wireless technologies that work at 2.45 GHz. The antenna is made to be as small as possible to be built into Wi-Fi, Bluetooth, cell phones, and ISM devices that use wireless communication. The suggested antenna can be used for a wide range of 2.45 GHz wireless communication tasks.

4. PARAMETRIC STUDIES

Many microstrip patch antenna parameters are dissected and analyzed in that section of the article. Some factors are return loss, VSWR, radiation pattern, gain, bandwidth, surface current, and efficiency. Further parameters include surface current. In designing antennas, the antenna gain, the reflection coefficient, and the power transfer efficiency are the factors that are evaluated. These factors are broken down even further into their directivity, radiation pattern, and beam width components. The antenna gain, its radiation pattern, and its directivity can all be defined with the pattern command. The beamwidth code makes it possible to observe the antenna's beamwidth and directivity. Based on the range of frequencies, the s-parameter made it possible to figure out the return loss and, in turn, the design's reflection coefficient [10].

4.1. Operating frequency and resonating frequency

The antenna can receive or send signals to other devices at this frequency. This frequency is referred to as the frequency. It is possible to calculate the operating frequency of a microstrip antenna if the height of the patch is known when the calculation is performed. Alternatively, the operating frequency can be chosen before the design process [35]. The frequency at which the antenna vibrates most strongly is called its resonating frequency (-10 dB). The resonating frequency will be far lower than the operating frequency most of the time. This is due to various factors, such as fringing fields. The resonant frequency is the frequency at which the patch receives the most significant amount of power or the frequency at which the impedance of the patch and feedline are most closely matched.

4.2. Feed for microstrip lines

The microstrip line feeding method is the simplest of all the feeding methods used. A microstrip line with an impedance of 50 ohms is attached to the patch in this configuration. The port is connected at the other end of the additional microstrip line introduced, which acts as a feeding point for the microstrip patch antennas. The length of the feeding line does not depend on any other characteristics. In contrast, the width is determined by applying the more traditional equations to the same frequency and impedance of 50 ohms [36].

4.3. Microstrip inset feeding system

Microstrip inset feed is an improvement made to the microstrip feed line since it was first introduced. In this feeding method, a feed point is determined by measuring a location anywhere on the surface of the rectangular patch. This location is chosen based on its proximity to the point at which the impedance of the patch coincides with the impedance of the microstrip feed line, which is 50 Ω. After that, the feed line is fastened to that specific position on the antenna. In most cases, the feed point for the rectangular patch is located at the one-third point of the width and the center point of the length. At this point, the impedance of the patch is 50 ohms [36].

4.4. Return loss (S_{11}) and bandwidth

The radiation that is reflected by the antenna in communication devices is referred to as "return loss," and the phrase "return loss" is used in communication devices [37]. When it comes to determining the amount of signal that an antenna can receive, the reflection coefficient is one of the most essential parameters that play a role. When using a patch antenna of excellent quality, the return loss value should be less than -10 dB to guarantee effective communication. By utilizing the s-parameter, it is possible to both define and measure the resonance frequency and the bandwidth of the antenna [38]. The reflection coefficient also called the return loss, is represented by (S_{11}). Because return loss in an antenna is a ratio of incident power to reflected power, the performance of an antenna is often dependent on having a good reflection coefficient or a return loss of at least -10 dB or greater than -15 dB. This is because return loss in an antenna is measured in decibels. Assuming that the reflection coefficient is 0, no power has been transmitted because it has been reflected from the antenna [39]. The bandwidth of an antenna is a crucial characteristic that, with the use of the s-parameter curve, may be determined. There has been a completion of the formulation of bandwidth [40].

$$\therefore \text{Bandwidth}=\frac{f_H-f_L}{f_C}\times 100\% \tag{8}$$

Where, f_H is higher frequency, f_L is Lower frequency, f_C is Centre frequency.

4.5. Voltage standing wave ratio

The VSWR is a measurement that determines how efficiently RF power is delivered from a power source to a load via a transmission line. This ratio is expressed as a percentage. The value of the VSWR ought to be somewhere in the range of 1 and 2 for the best possible transmission. The greater the value's proximity to one, the better the impedance matching [38]. The term "standing wave ratio" can also refer to the VSWR. This ratio is always considered a real number, specifically a positive real number [39]. Also, regarding practical applications, VSWR is invariably a number that is both real and positive. The antenna and transmission line are well-matched when the VSWR is low. The number 1 represents the ideal VSWR for an antenna. If the antenna and feed are not matched, then some of the available electrical energy will not be able to transmit to the antenna [41]. As a function of the VSWR, an antenna's reflection coefficient is shown here [42].

$$VSWR = \frac{\Gamma+1}{\Gamma-1} \tag{9}$$

4.6. Gain and directivity

The "gain" refers to the ratio of the power density at each site of a directional antenna to the power density at the same spot of an isotropic antenna fed by the same power source as the directional antenna. The ratio between the two power density levels serves as a measure of gain. A term known as "antenna gain" can be used to describe the amount of power transferred in the direction of peak radiation from an isotropic source [40]. The term "directivity" refers to the ratio of the radiation intensity in a particular direction emanating from an antenna to the radiation intensity that has been averaged out over all directions [38]. The directivity of an antenna is a description of the directional characteristics of the antenna. Since the radiation pattern is the only thing that controls it, it refers to the antenna's ability to point in a particular direction [43].

$$\therefore \frac{\text{Maximum radiation intensity}}{\text{Average radiation intensity}}=\frac{U_{max}}{V_0} \tag{10}$$

4.7. Efficiency, radiation efficiency, and surface current

"Efficiency" is a term that describes the amount of energy that must be injected into an antenna to be able to communicate effectively [44]. The amount of power supplied to an antenna and the intensity with which it emits or dissipates can be used to determine how effective the antenna is. Most of the energy sent to the low-efficiency antenna is either lost due to losses within the antenna itself or because of an impedance mismatch that causes it to reflect away [40].

$$\therefore \text{Antenna efficiency} = \frac{\text{Gain (dBi)}}{\text{Directivity(dBi)}} \times 100\% \quad (11)$$

The radiated efficiency of an antenna is multiplied by the impedance mismatch loss of the antenna when it is linked to a transmission line or a receiver to get the total efficiency of the antenna [45]. The antenna's radiation efficiency is measured by the ratio of the total power it sends out to the net power it receives from a connected transmitter [38]. Surface current is a type of electric current caused by applying an electromagnetic field, and it is most commonly found in metallic antennas [46]. Besides, how the current is spread on the antenna helps it send out electromagnetic waves more effectively [47].

5. ANALYSIS AND RESEARCH GAP

In the past few years, there has been more demand for small antennas for wireless communication. Because of this, microwave and wireless engineers are now more interested in learning how to make small microstrip antennas. A small, light antenna is likely chosen for a wireless communication device because this type of equipment needs to move around quickly. Using a microstrip antenna is one of the best applications. To make an antenna that can be used for wireless communication, you need to develop one that can work on multiple frequencies. This is because of several things, but the main one is that there are many types of wireless communication technologies and many different telecom companies that use different frequencies. [48]. In this section, several parametric analyses of the proposed work are done and given. Tables 1 and 2 present the results of various previously published papers. The substrate materials, loss tangent, and thickness of several publications that have been published in the past are discussed in Table 1. It has been established through the examination of earlier studies that various substrate materials, such as FR-4 substrate, Rogers RT5880, and other materials, have been utilized for various applications, respectively. Because there are a variety of values possible for the loss tangent and thickness.

At this very moment, the entire world has begun to become agitated about the design of antennas. Microstrip patch antenna design was one of the many sorts of antennas that the researchers produced, and they impressed people worldwide with one of their designs. The utilization of microstrip patch antennas, in addition to the utilization of other antennas, is expanding at a rapid pace. The discrepancies between the articles previously worked on by various researchers are highlighted in Table 2, which can be found below. Table 2 displays the values of return loss, gain, VSWR, and bandwidth found in various studies published in the past.

Table 1. Antenna substrate materials have varying loss tangent, thickness, directivity, and efficiency

Ref.	Operating frequency (GHz)	Substrate materials	Dielectric permittivity (ε)	Thickness (mm)	Directivity (dBi)	Efficiency (%)
[3]	2.45	Roger RT/duroid5880	2.2	0.035	8.587	94.24
[7]	2.40	FR4_epoxy	4.4	0.2	-	-
[15]	2.44	FR-4	4.3	1.6	-	-
[17]	2.45	FR-4	4.3	7	5.483	55.74
[18]	2.45	FR-4	4.7	1.6	2.76	90.49
[20]	2.45	FR-4	1.2	0.46	9.0	73
[21]	2.45	Roger RT/duroid5880	2.3	0.787	8.012	83.06
[22]	2.45	FR-4	3.8	1.5	7.48	73.39
					9.89	80.88
[25]	2.45	Roger RT/duroid5880	2.2	3.175	8.28	97.82
[31]	2.46	FR-4	4.3	1.6	-	-
[32]	2.45	FR-4	4	0.7	-	89
[33]	2.45	FR-4 (lossy)	4.3	1.6	14.7	73.46
[34]	2.45	PF-4	1.06	2	5.109	77.17
[49]	2.45	Roger RT/duroid5880	2.2	1.5		95.57
[50]	2.42	Rogers lossy R03206	6.15	1.6	2.787	-
[51]	2.45	Roger RT/duroid5880	3	0.035	7.267	96
				0.035	7.027	97
[52]	2.45	FR-4	4.4	1.6	-	-
[53]	2.42	FR-4	4.4	1.6	5.78	94.11
[54]	2.45	Teflon	2	0.8	-	-
[55]	2.45	FR-4	4.4	1.6	-	-
[56]	2.4	FR-4	4.4	3.6	6.6163	67.76

Table 2. Comparison between other published antennas

Ref.	Operating frequency (GHz)	S_{11} (dB)	Gain (dBi)	VSWR	Bandwidth
[3]	2.45	-12.542	8.092	1.617	0.0349 MHz
[7]	2.40	-19.35	9.2	1.2414	44.4 MHz
[15]	2.44	-27.17	2.97		146.5 MHz
[17]	2.45	-17.47	3.019	1.311	520 MHz
[18]	2.45	-19.62	3.050	-	88 MHz
[21]	2.45	-22.58	6.655	1.160	25.5 MHz
[22]	2.45	-38.5	5.49	1.02	59 MHz
		-37.67	8.0	1.02	79.2 MHz
[25]	2.45	-17.85	8.1	1.29	-
[26]	2.45	-25.28	6.29	-	32.02 MHz
[27]	2.45	-23.18	2.91	-	-
[28]	2.45	-23.4	-	1.17	0.1 GHz
[32]	2.45	-16.52	-	-	50 MHz
[33]	2.45	-29.5	10.8	-	200 MHz
[49]	2.45	-31.5224	8.31	1.5	89.79 MHz
[50]	2.42	-22.242	-	-	50.473 MHz
[51]	2.45	-28.28	7.119	-	24 MHz
		-22.03	6.968		27MHz
[52]	2.45	-41.599	-	-	66 MHz
[53]	2.45	-16.207	5.44	1.5	160.24 MHz
[54]	2.45	-29.3	5.226	-	-
[55]	2.45	-45.36	1.37	-	183.3 MHz
[56]	2.4	29.0791	4.483	0.8904	-
[57]	2.45	-30	-	1.025	-
[58]	2.45	-46.45	5.202	1.009	54.5 MHz

6. CONCLUSION

This study explores and analyses the many designs of microstrip patch antennas, as well as the uses that these antennas have in modern technology. Additionally, the survey discusses the applications that these antennas have. This is because the applications and utilization of antennas are growing daily. Microstrip patch antennas are inexpensive, lightweight, and simple to build, making them an excellent choice for wireless communication and other potential applications. This device has a low power output, a limited bandwidth, and a low gain. One of the topics covered in this paper is the enhancement of microstrip patch antennas. There is an improvement in patch antenna gain, size, and return loss when the ground construction is defective. In future work, the combination of these methods may be utilized in designing and improving the performance of various microstrip antennas intended for use in wireless communication systems.

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BIOGRAPHIES OF AUTHORS

Md. Sohel Rana get a B.Sc. engineering degree in electrical and electronic engineering from Prime University (PU), Dhaka, 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), Dhaka, Bangladesh. He completed his second M.Sc. in engineering (master of science in engineering in information systems security) from Bangladesh University of Professionals (BUP), Dhaka, Bangladesh, in 2022. He completed his third master of science (M.Sc.) in electrical and electronic engineering at Independent University, Bangladesh (IUB), Dhaka, Bangladesh, in 2023. His research interests include microstrip patch antenna, wireless communication, image processing, renewable energy, solar cells, biomedical engineering, control systems, and power electronics. He has published more than 42 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-9100, Bangladesh. He can be contacted at email: sohel.rana@uits.edu.bd.

Tanvir Rahman Rocky is in the final year of his undergraduate studies at the Northern University of Business and Technology in Khulna. The university's Electrical and Electronic Engineering department is where he is pursuing his degree in computer science. Some of the scientific fields he is interested in include the design of antennas, VLSI, wireless communication, and renewable energy. Additionally, he has contributed to writing two papers related to his research studies. He can be contacted at email: tanvirrehman872@gmail.com.

Md. Arif Islam is currently enrolled as an undergraduate student in the Department of Electrical and Electronic Engineering at the Northern University of Business and Technology in Khulna. He is currently in his final year of studies. The individual's scientific pursuits encompass the fields of antenna design, wireless communication, and renewable energy. He can be contacted at email: arifislam0212@gmail.com.

Al Mamun is currently in his final year of undergraduate study at Northern University of Business and Technology Khulna, where he is enrolled in the Electrical and Electronic Engineering undergraduate program. Wireless communication, antenna design, and renewable energy are some of the topics that he is interested in researching. He can be contacted at email: mamun.ahamed371717@gmail.com.

Sanjay Kumar Joy is an undergraduate final-year student at Northern University of Business and Technology Khulna in the Electrical and Electronic Engineering department. His research interests are Antenna Design, Renewable energy, and wireless communication. He can be contacted at email: joysarker584@gmail.com.

Saikat Mondal is in the 2nd year of his undergraduate studies at the Northern University of Business and Technology in Khulna. He is currently pursuing a degree in the Electrical and Electronic Engineering department at the institution. The development of antennas, wireless communication, power systems, and alternative energy sources are some of the scientific endeavors that he is interested in pursuing. He can be contacted at email: nubtk.saikat@gmail.com.

Md. Toukir Ahmed graduated from Rajshahi University of Engineering and Technology (RUET) with an M.Sc. engineering degree in computer science and engineering (CSE) and graduated from the same University with a B.Sc. engineering degree in CSE. Currently, he is working as a full-time faculty member at the IoT and Robotics Engineering Department at Bangabandhu Sheikh Mujibur Rahman Digital University, Bangladesh. Previously, he worked as a full-time faculty member at the Information and Communication Technology (ICT) and CSE departments at Bangladesh Army University of Science and Technology, Saidpur. Also, he worked as a full-time faculty member at the CSE department at Bangladesh University, Dhaka. He can be contacted at email: toukircse14@gmail.com.

Md. Hasibul Islam is currently serving the Computer Science and Engineering Department of Northern University of Business and Technology Khulna as a Lecturer. He completed his B.Sc. (Engg.) from the Computer Science and Engineering Discipline of Khulna University, Bangladesh. He is currently pursuing his M.Sc. (Engg.) from the same discipline of Khulna University, Khulna, Bangladesh. His research interests are in software engineering, communication engineering, and automation. He can be contacted at email: hasib1428@cseku.ac.bd.

Sourav Pal graduated from Shahjalal University of Science and Technology (SUST), Bangladesh, with a bachelor of science in electrical and electronic engineering degree in 2020. Currently, he is working on fuzzy logic-based stabilization of microgrid and antenna design. Some of his research interests are renewable energy, smart power grids, frequency control and power quality issues, system development for hybrid AC-DC grids, power demand response issues, power electronics, microstrip patch antennas, and wireless communication. At present, he is working as a Lecturer at the Northern University of Business and Technology Khulna, Khulna-9100, Bangladesh in the Department of Electrical and Electronic Engineering. He can be contacted at email: adittyyapaul007@gmail.com.

Imran Chowdhury received a bachelor's degree in electronic and communication engineering from the University of Information Technology and Sciences, Bangladesh in 2011, and a master's degree in electrical engineering from the Texas A&M University-Kingsville, USA in 2015. Currently, he is working as an assistant professor in the Department of Electrical and Electronic Engineering at Northern University Bangladesh. He also worked at the University of Information Technology and Sciences, Bangladesh; Rajshahi Science and Technology University, Bangladesh; and Texas A&M University-Kingsville, USA. He started his career in 2011 and has more than 10 years of teaching and research experience. He is an author/co-author of 17 scientific contributions, including articles in international refereed journals and conferences. He can be contacted at email: imranchd@outlook.com.

Omar Faruq Ph.D. research fellow, Department of Electrical and Electronic Engineering (EEE), Bangladesh University of Engineering and Technology (BUET). Received his post-graduate degree from the School of Communication and Information Engineering, Chongqing University of Posts and Telecommunications (CQUPT), China. And graduate degree in electrical and electronic engineering from Daffodil International University, Bangladesh. His research interests are free-space optical communication, wireless communication, image and signal processing, machine learning, and deep learning. He is trying to develop long-distance wireless communication with top speed and noiselessness. He can be contacted at email: smomarfaruq99@gmail.com.