Microstrip patch antennas for various applications: a review

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ABSTRACT

This paper aims to review microstrip antennas for various applications. The design of microstrip patch antennas is a new research field developed for use in 5th generation communication applications. An antenna is a collection of multiple devices connected together that function as a single antenna to send or receive radio waves. Antennas can be of different shapes and sizes. The microstrip patch is an antenna pattern that is light in weight, low profile, and focuses on producing results. In the future, microstrip patch antennas may be used for some 6G communication systems applications. In addition, 6G communication applications can be created on other devices, including biomedical, autonomous vehicles, vehicle-to-vehicle (V2V) communication, internet of things (IoT), machine learning, Artificial Neural Network Algorithms, radar, and wireless communication. In the past, the multiple input, multiple output (MIMO) pattern was a standard geometry used in 4G wireless applications. This paper discusses the geometric structures of antennas, various analysis methods for antenna characteristics, antenna dimensions, and many different types of antennas. Also, it will discuss the previous papers' substrate materials, loss tangent, thickness, return loss, bandwidth, voltage-standing-wave-ratio (VSWR), gain, and directivity.

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1. INTRODUCTION

Antennas are an essential component of the telecommunications industry. To put it more simply, it is a transducer that changes radio signals into electrical energy and electrical energy into radio signals. Wireless communication technology enables the transmission and reception of signals among people who live in geographically inaccessible locations so that they can communicate with one another. Nowadays, a wide variety of applications make use of the microstrip patch antenna (MPA), which is popular due to its low volume, low cost, and low profile.

The performance of the microstrip patch antenna can be improved by optimizing its design for a number of different factors. The use of a printed antenna in wireless communication is possible at a variety of different frequencies of operation. Today we live in a fast-paced and ever-evolving world of wireless communication. Dual or multiband antennas have played a significant role in the evolution and expansion of various wireless service application types. Within the realm of microstrip antennas, there have been a significant number of design and development activities focused on application specifications. Both microstrip patch antennas and predictable antennas are common types of antennas. Predictable antennas have better analysis and more benefits than microstrip patch antennas. In order to carry out all of these wireless applications, we require an antenna that is both very compact and very well organized.

Antennas play an increasingly important role in our day-to-day lives. Alongside the development of mobile and cellular technology during this time period came the development of more convenient antenna technology. Microstrip patch antennas have a bright future because they are small and light and can work at two or three frequencies. They can also support both circular and linear polarization. The fact that MPA have all of these characteristics demonstrates that they are suitable for a wide variety of application systems [1]. A ground plane is placed on one side of a dielectric substrate, and a radiating patch is placed on the opposite side. This is how it is constructed. The radiating patch is located on one side of the substrate. The diagram labeled Figure 1 provides a summary of the MPA. The patch is typically constructed out of conducting material such as copper or gold, and it can take any of the possible shapes (such as square, rectangular, dipole, circular, traiangular, ring elliptical) that are depicted in Figure 2 [2].

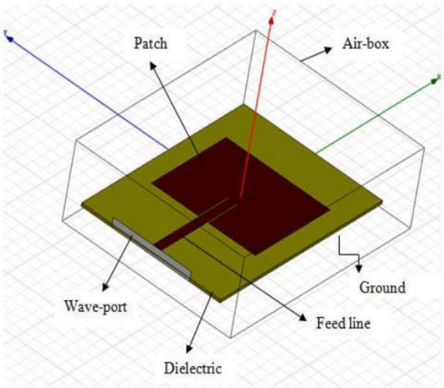

Figure 1. Microstrip patch antenna

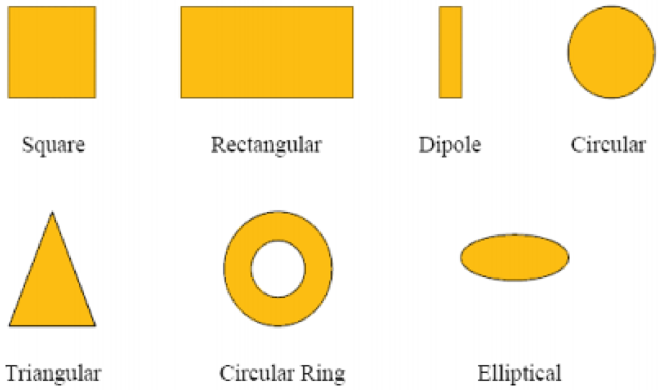

Figure 2. Microstrip antennas for different shapes

The paper is divided up into four sections for the purpose of the organization. In addition to that, the following is the structure of the paper: In section I, the introduction is presented; in section 2, a literature review is presented; in section 3, their related work scheme is provided; and finally, in section 4, the conclusion is presented. All references will be given in the references section.

2. LITERATURE REVIEW

In this section will discuss different applications of microstrip patch antennas. In this paper will review where the authors have applied microstrip patch antennas. This antenna has been used in various cases at present. The use of these antennas is increasing with the present time and technology. Its use in various sectors, including wireless communications, medical science, electronics, wireless power transfer, autonomous vehicles, medical physics, and machine learning, is increasing daily. This antenna has been used in 6G applications in different countries.

Gburi *et al.* [3], presents the design and simulation of hexagonal microstrip patch antennas operating at 3.5 GHz. The 1×8 array antenna that was proposed makes use of the microstrip feed line as one of its components. Because of its directional radiation, the base station is able to provide network connectivity that is both high-quality and high-capacity. This antenna is designed for use in point-to-point connections that span great distances. The completed antenna demonstrated a gain of 6.938 dB at 3.5 GHz and a return loss of -10 dB. According to the findings presented in the study paper [4], the antenna has a directivity of 7.6 dB, a bandwidth of 1.06 GHz, 7.5 dB, and a reflection coefficient of -20.95 dB. It operates at a frequency of 27.97 GHz. Furthermore, its effectiveness is at a level of 99.98%. This article looks into how to patch antennas can be used in 5G wireless networks and how they can be set up.

Tsao *et al.* [5], developed a 2-port dual-band and dual-polarization multiple input, multiple output (MIMO) antenna for 5G mobile applications at 28 and 38 GHz. Both orthogonal polarization and frequency diversity were features of the MIMO antenna. The antenna had a 5.7 dBi gain across the frequency range of 27.5–30.9 GHz and a 6.28 dBi gain across the frequency range of 37.3–44.6 GHz. It is suitable for use in 5G antenna arrays for femtocells and microcells. Subitha *et al.* [6], a straightforward, slotted microstrip square patch antenna that can operate at millimeter wave frequency. It is designed to be utilized in wireless communication systems that operate at 5G and beyond 5G speeds. In contrast to the antenna that has not been optimized, the optimized antenna yields results that are significantly better. It has a return loss of -38.3 dB and a maximum gain of 6.46

dB. Because wireless communication devices that support 5G and 6G tend to be more compact than their predecessors, the antenna has dimensions of 5.12×5.12×0.9 millimeters on each of its three sides.

Wang *et al.* [7], presents a novel compact monopole-like end-fire antenna with reconfigurable radiation patterns that is intended for use in applications utilizing 5G. The antenna is broadband and has a compact size. This study puts forward a half-sized monopole-like end-fire structure with a wideband response and begins the analysis. This structure is based on the mirror principle. The proposed antenna is small in size, has a straightforward design, can switch between multiple beams in a flexible manner, and has a wide frequency range. It is a strong contender for 5G new radio as well as other applications operating below 6 GHz.

Thaher *et al.* [8], According to the size of the proposed antenna is on FR-4, and it is able to achieve five bands at resonance frequencies that are (9.658 GHz), (11.68 GHz), (16.054 GHz), (21.28 GHz), and (29.704 GHz), respectively. This antenna is used in wireless applications for use in the X-band, Ku-band, Ka-band, and K-band spectrums, as well as 5G. In addition to that, it works for radar, satellite communications, wireless network computers, medical communication devices, and local multi-point TV to detect vehicles traveling at high speeds. Alhaqbani *et al.* [9], describes wideband MIMO antenna design for 5G smartphone terminals. The MIMO antenna array that has been proposed is made up of 8-port dual-polarized L-shaped lines that highly excite radiating slots at the four corners of a compact mobile unit that measures 75 mm^2×150 mm^2. The diversity MIMO antenna for the smartphone 8×8 is designed to support commercial sub-6 GHz 5G communications. It also covers the 3.5 GHz band and has high decoupling between the antenna ports.

Khan *et al.* [10], discuss the design of a MIMO antenna array that is suitable for use in 5G millimeter-wave (mm-wave) communication systems. The proposed configuration uses two antennas. Each antenna array has four evenly-spaced elements, and two arrays are assembled 90° apart. The proposed MIMO antenna array covers 37 GHz, a 5G millimetre-wave band. ECC and DG are below the standard threshold. Over 85% of the MIMO antenna array's radiation efficiency is within the operating frequency band. The proposed design could be used in 5G millimeter-wave systems.

Rana *et al.* [11], designs and reported a microstrip patch antenna with the intention of applying it in the field of future wireless communication technology. The goal of this study was to find a way to reduce the amount of return loss while simultaneously increasing gain and reducing voltage-standing-wave-ratio (VSWR). Rana *et al.* [12], investigated a 5G high-band slotted microstrip antenna. Using the antenna, high bit rates, decreased traffic, and increased user retention are all possible. The return loss, gain, and bandwidth of a rectangular microstrip antenna can all be improved by superimposing a square slot on top of a circular slot in the antenna. The provided antennas improve return loss, gain, and their bandwidth.

Rana *et al.* [13], presents a hash-shaped slotted microstrip antenna for wireless communication. The antenna reduces freight and increases consumer engagement while increasing bit rate. By implementing a hash-shape slot into the patch of a traditional rectangular microstrip antenna, the return loss, gain, and bandwidth are improved to -32.159 dB, 8.07 dBi, and 3.848 GHz, respectively. Biddut *et al.* [14], the authors proposed ultra-wide multi-slotted microstrip patch antenna as a potential solution for use in upcoming wireless communication technologies. This antenna would operate in the V-band. To increase bandwidth, specific random slots have been inserted into the patch. This method presents a promising alternative for developing future wireless communication technologies. A gain of 7.486 dBi, a return loss of 18.117 dB, and a bandwidth of 21.064 GHz are characteristics of the antenna.

Singh *et al.* [15], a microstrip patch antenna for UWB applications is designed for 3.1 to 10.6 GHz. This work designs a microstrip antenna with a hexagonal patch. The proposed microstrip patch antenna is hexagonal in shape and has a radiation efficiency of 90.88%. The peak gain of the antenna is 5.32 decibels. Applications utilizing UWB can be carried out with its use. Rosaline [16] discusses the design of a compact dual band microstrip antenna that is based on a split ring radiating element and a split ring resonator. This antenna is intended to operate at two different frequencies simultaneously. The dimensions of the antenna are 20x20x0.8mm3. It provides coverage for 2.5/5.2/5.8 GHz IEEE 802.11 b/g/a wireless local area network (WLAN) frequencies and has an impedance bandwidth of between 250 MHz and 860 MHz at -10 dB. The proposed antenna is built, and the measured results match the simulations.

Nissanov *et al.* [17], suggests and investigates novel microstrip antenna gains for 6G cellular communication at 112.5 GHz, with a peak gain of more than 24 dB. The first proposed antenna has a peak directivity of 27.27 dB, a gain of 25.7 dB, a bandwidth of 24.89 GHz, and a total efficiency of 77.95%. The second proposed antenna has a peak directivity of 27.2 dB, a gain of 25.74 dB, a bandwidth of 18.3 GHz, and a total efficiency of 77.95%. Based on these results, it appears that the designs that were proposed are appropriate for use as 6G mm-wave/THz antennas. Foysal *et al.* [18], a tooth-shaped antenna for autonomous vehicles as well as a 77 GHz antenna that was designed is both described. Gain is increased while mutual coupling is decreased thanks to the patch antenna design. The current distribution the tooth-shaped patch antenna is 1.3610.303 A/m, and the patch antenna has a gain of 9.4 dB. The conventional patch values were 7.2 decibels (dB) and 4.99 times 10-2 amps per meter (A/m). The return of a tooth-shaped antenna is -37.9441 decibels. The antenna that was designed is something that future 6G autonomous vehicles will be able to use.

Mollah *et al.* [19], describes a graphene microstrip patch antenna. It has 2.45 GHz for wireless communication. The VSWR, return loss, H-plane radiation pattern, and input impedance are all displayed there. According to the simulation, the returns loss is –23.673dB, the gain is 6.801dB, and the directivity is 7.302 decibels per inch and efficiency is 93.14%. In this article, the fabrication of a microstrip patch antenna using graphene as the substrate is discussed. Graphene is used in wireless communication today. Microstrip patch antennas perform better and anticipate better than others. Finally, this paper developed a graphene-based microstrip patch antenna design.

Hussain *et al.* [20], this body of work resulted in the development of a wideband microstrip patch antenna that was designed specifically for use in V-band applications. The proposed design demonstrates an impedance bandwidth that ranges from 63 GHz to 74 GHz, and the proposed antenna provides a very high gain of > 9.5dB in the bandpass region. The work that was proposed is a potential candidate for 5G communications in the V-band because of its high gain, straightforward geometrical configuration, wide operational band, and small size. Additionally, the operational band is relatively wide.

Talukder and Islam [21], simulated an e-shaped slotted Microstrip patch antenna using HFSS for 5G, GPS, and WiMAX/WLAN applications. Multiband operation is being studied with a DGS microstrip rectangular patch antenna with a narrow slot. The proposed antenna resonates at 4.6 GHz, 8 GHz, and 10 GHz with 90 MHz-500 MHz bandwidth and 8.03 dB gain. Kantipudi *et al.* [22], analyzes and simulates a novel approach to designing a microstrip antenna for ISM bands. The antenna's resonant frequency depends on its geometry and dimensions; it is analyzed and synthesized using an artificial neural network (ANN) model. Length, width, and height for the operating frequency are calculated to design the antenna. RBF, MLP, and Conventional formula geometries match well. ANN model of design can be extended to RF and microwave components. This ANN antenna design can be extended to metamaterials antennas for communications.

Al-Hetar and Aqlan [23], describes with the growing need for bandwidth, millimeter wave (MMW) systems are finding commercial applications. A patch shape can be engineered to have gain and bandwidth. The paper proposes a patch antenna shape. The microstrip antenna under consideration has a bandwidth of 5 GHz and a gain of 8.2 decibels. The simulation reveals substantial shifts in the radiation pattern as well as the bandwidth for passive MMW imaging in the map array. Ruslan *et al.* [24], designs a microstrip patch antenna using rubber substrates with different carbon filler concentrations: natural rubber, 20% carbon filler, 25% carbon filler, and 50% carbon filler. Performance of the designed antennas is compared to poly dimethyl siloxane (PDMS) and RO3003. Return loss, bandwidth, and gain are the three metrics that are used to evaluate the performance of antennas. The effect of antenna bending on performance is also discussed.

Li *et al.* [25], present a slot microstrip patch antenna that is fabricated using ink-printing and is intended for use in 5G applications. The antenna has a gain of 5 dBi on average and operates at three distinct frequency bands: 5.73 GHz, 6.16 GHz, and 8.34 GHz. additionally, the antenna operates at all of these frequencies simultaneously. It is composed of three layers and includes a patch that is slotted. Fadhil and Thaher [26], a new microstrip patch antenna for GPS is designed. The proposed model has a gain of 4.974 dBi and. rectangular patches with two truncated corners make up GPS antenna elements. A great number of slots are cut into both the patch and the ground plane in order to achieve the optimal return loss resonant frequency. The model was developed and validated using a vector network analyzer (VNA). The authors in Zerith and Nesasudha [27] describe how they made a brand new GPS microstrip patch antenna. This article discusses a meandering-shaped microstrip patch antenna that works in the ISM band at 2.45 GHz. The simulation results show the antenna has good qualities, such as gain, return loss, bandwidth, directivity, and good radiation. The antenna that has been proposed is perfect for usage in wireless body area network (WBAN) because of its high level of adaptability in addition to its tiny size.

Teresa and Umamaheswari [28], discuss 5G microstrip antennas at 28 GHz. Three slotted microstrip antenna models are suggested. 28 GHz is used for 5G antenna design. Analyze and compare antenna return loss, bandwidth, efficiency, gain, and directivity. Slot configurations boost bandwidth and reduce area. Simulated using a high-frequency structure simulator, the proposed antennas are 7×7 mm. This article outlines [29], a fresh approach to the design of a broadband microstrip antenna that is suitable for implementation in 5G systems. The proposed antenna operates at a central frequency of 28 GHz and is capable of functioning in the frequency band designated for local multipoint distribution service (LMDS). The antenna that is discussed in the article has a low reflection coefficient of -22.51 dB, a high energy gain value of 3.6 dBi, a wide operating band of 5.57 GHz, and high energy efficiency. All of these characteristics contribute to the antenna's overall performance.

Viswanadh [30], a microstrip antenna array is discussed in the paper referred to as for use in millimeter-wave applications in the frequency ranges of 24.25 GHz to 27.5 GHz and 26.5 GHz to 29.5 GHz. The end product is a 4-element antenna array that has dual-band S_{11} parameters of -32.88 dB at 24.67 GHz and 8.67 dB gain, and -35.07 dB at 29.35 GHz and 10.30 dB gain. The final structure's return loss, gain, and VSWR are compared to the initial and intermediate designs. Gundewar *et al.* [31], a 900 MHz microstrip patch antenna is designed in the proposed system, and different materials are tested for moisture content. Various industries need accurate moisture content measurements for materials or grains. Microstrip and horn antennas are used to measure sample moisture noncontactly. Gradually increasing the sample water content and measuring return loss. Moisture increases returns.

Kaur *et al.* [32], a Neural Network Model for designing an ultra-wideband microstrip patch antenna. Reduced ground size increases the proposed design bandwidth. The proposed method's results agree well with electromagnetic (EM) simulation software. Ultra-wideband antenna matching is used in the paper staircase. Comparing experimental and simulation results with artificial neural network results was satisfactory. Radial basis function (RBF) network is more accurate and faster for the proposed design. Ali *et al.* [33], introduces a compact microstrip patch antenna for WBAN 2.4 GHz applications. The design includes a radiating patch and a ground plane. The radiating patch antenna is 62×43×1.67 mm. The proposed on-body and off-body antenna has compact, stable far-field radiation and negligible specific absorption (SAR). Off- and on-body efficiencies of 53% and 46% are higher than recent literature. Simulated and measured results agreed well. Due to its good results, the proposed design can be used for ISM-band WBANs.

Asokan *et al.* [34], an Ansoft HFSSV13 microstrip patch antenna is designed. Double-sided microstrip patch antennas are designed. The 2.4 GHz antenna is made of 4.4 dielectric constant FR4 material. The designed antenna has a return loss of less than 10 dB for ISM and WLAN applications. Return loss, VSWR, mutual coupling, gain, and radiation pattern have been simulated and analyzed. Priya *et al.* [35], a simple microstrip patch antenna is designed for WLAN applications. It describes a high-gain, single-band microstrip antenna printed on FR-4 with a ground plane. The proposed patch antenna covers 2.4 GHz with a -39.008 dB return loss. ADS 2014 was used to simulate. Casu *et al.* [36], the designed antenna works well for WLAN and this study examines the design and implementation of 41 and 81 microstrip patch antennas (arrays) by utilizing IE3D software and FR4 dielectric material with a permittivity of 4.28, tangent loss of 0.002, and height of 1.6 mm. The height of the antennas is measured in millimeters. An array of microstrip patch antennas for use in WLAN, complete with microstrip line feed and power dividers. Sharma *et al.* [37], a new microstrip antenna structure for wi-fi systems is investigated. This work aims to develop a cost-effective indoor/outdoor patch antenna. Radiation pattern, return loss, VSWR, directivity, and gain are evaluated. HFSS simulates and optimizes the proposed antenna. Simulations confirm the designs' effectiveness. The proposed antenna is tested after being designed and optimized in simulation software.

An application-specific rectangular microstrip patch antenna designed for use in the 915 MHz band is discussed in this research [38]. ZigBee and Bluetooth are two of these applications' many uses. In recent years, printed antennas have been a significant contributor to the creation of antennas that operate at a variety of frequencies. The suggested antenna has good omnidirectional radiation patterns and operates at frequencies ranging from 902 MHz to 928 MHz. In Table 1 discusses the substrate materials, loss tangent and thickness of various previous papers. By studying the previous papers, it is known that different substrate materials (FR-4 substrate, Rogers RT/Duroid 5880) have been used for different applications. For which different values of loss tangent and thickness are available.

Table 1. Substrate materials used in different antennas, and their loss tangent and thickness are given different values

Ref.	Substrate materials	Loss tangent	Thickness
[8]	FR-4 substrate	0.002	0.035 mm
[10]	Rogers RT5880	0.0009	0.254 mm
[11]	Rogers RT/Duroid 5880	-	0.345 mm
[12]	FR-4 substrate	0.025	0.8 mm
[13]	FR-4 substrate	0.025	0.8 mm
[14]	Rogers RT 5880	0.0009	0.5 mm
[15]	FR-4 substrate	0.02	1.59 mm
[18]	FR4 substrate	0.02	0.8 mm
[20]	Rogger/RT Duriod 5880	0.0009	0.508 mm
[36]	FR4 substrate	0.002	1.6 mm
[38]	FR-4 substrate	0.02	1.6 mm
[39]	RT Duroid 5880	-	0.5 mm
[40]	RT Duroid 5880	0.0009	0.127 mm
[41]	RT/Duroid 5880	-	0.254 mm
[42]	RT Duroid 5880	0.0009	0.127 mm
[43]	Rogers RO4350	-	-
[44]	Rogers RT 5880	0.0009	0.17 mm
[45]	Rogers RT 5880	0.2	-
[46]	RT Duroid 5880	0.0009	-
[47]	FR-4 substrate	0.0010	-
[48]	Rogers RT 5880	-	1.57 mm
[59]	Rogers RT 5880	-	0.2 mm
[61]	Rogers RT/Duroid 5880		0.3451 mm
[62]	Rogers RT 5880	0.0009	0.5 mm

At present, the whole world has started to stir about antennas design. The researchers designed different types of antennas and impressed the whole world, among them microstrip patch antenna design. The use of microstrip patch antennas among other antennas is increasing at a great rate. Table 2 highlights some of the differences between the papers previously worked on by various researchers. The values of return loss, gain, VSWR and bandwidth of various previous papers are shown in Table 2.

Table 2. Comparison between other published antenna

Ref.	S_{11} (dB)	Gain (dB)	VSWR	BW (GHz)
[11]	-20.03	5.23	1.22	2.11
[12]	-48.877	6.51	1.0072	3.088
[13]	−32.159	8.07	1.14	3.484
[14]	– 18. 117	7.486	-	21.064
[19]	–23.673	6.801	2	13.83
[26]	- 35.854	4.974	1.0328	1.575
[27]	-26.82 dB	1.9	-	100 MHz
[35]	-39.008	4.685	-	2.4
[43]	-19.61	6.58	1.82	10
[44]	-	9.21	-	27.3
[47]	-35	2.73	Less than 2	915 MHz
[48]	-33.4	10	-	**3.5**
[49]	-13.48	6.63	1.538	0.847
[50]	-18.27	4.46	2.13	0.2
[51]	-12.54	5.5	1.6	3.5
[52]	-17.4dB	6.72	1.27	28
[53]	-42	9.82	-	1.29
[54]	-16	2.28	-	1.44
[55]	-43	7.69	-	0.769
[56]	-40.28	5.8	1.02	200 MHz
[57]	-22.10	3.53	1.16	27.7
[58]	-33.02	7.17	1.04	-
[59]	-	6	7	
[60]	-42.97	5.2	0.12	-
[61]	-38.348	8.198	1.024	3.464
[62]	-43.77	8.42	1.013	3.033

3. CONCLUSION

The various designs of microstrip patch antennas, as well as the applications these antennas have in contemporary technology, are analyzed and discussed in this survey. For which the application and use of antenna is increasing day by day. Microstrip patch antennas are lightweight, easy to fabricate, and low cost, making them ideal for wireless communication and other fields. Its low gain, narrow bandwidth, and low power. This paper discusses ways to improve microstrip patch antennas. Defective ground structure improves patch antenna gain, size, and return loss. The combination of these methods could be used in the design and improvement of the performance of a variety of microstrip antennas for use in wireless communication systems in the work that will be done in the future.

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