Microstrip patch antenna review on various parameters, methods and its applications

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ABSTRACT

The implementations of the microstrip patch antenna for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) are analyzed in the literature in this research. Dual or multiband antenna has played a significant part in meeting the expectations of wireless service in this quickly developing world of wireless communication. Basically, a transitory guide, an antenna is a device that emits or absorbs radio waves. Numerous benefits exist for microstrip patch antennas, including affordability, portability, simplicity of construction, and compatibility with integrated circuits. This has several important uses in the military, radar, mobile communications, global positioning system (GPS), remote sensing, and more. In mobile devices like portable computers and smartphones, WLAN and WiMAX are often used.

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1. INTRODUCTION

The fastest-growing area of technology in the twenty-first century that has people talking about social life is wireless networking. Numerous homes, commercial buildings, and universities now have access to new wireless local area networks. Microstrip antennas (MSA) are appealing because of their low profile, light weight, simple production, and mounting host compatibility. A two-layer parallel conductive sandwich divided by a single, thin dielectric substratum is what is referred to as a microstrip unit. The top conductor is a simple circular or rectangular resonant patch [1]–[5], while the bottom conductor is known as ground plane. The geometric shapes of the metallic patch, which is often made of Cu or Au, might be rectangular, round, triangular, elliptical, and ring-shaped.

Different feed mechanisms are available for microstrip patch antennas. These tactics may be separated into contacting and non-contacting categories. The radio frequency (RF) power is delivered directly to the radiating patch during the contacting process using a microstrip line as a connecting element. The non-contacting approach uses electromagnetic field coupling to move power from the microstrip line to the radiating layer. Different configurations of the MSA feed are possible, including coaxial, aperture coupling, microstrip line, and proximity coupling. However, the coaxial feed and the microstrip line are both relatively easier to create. Because coaxial cable input impedance is typically 50 ohm, coaxial probe feed is employed because it is user-friendly. The patch has several spots with 50 ohm impedance [6]–[10]. The sizes and weights of the numerous wireless electronic systems have quickly decreased as a result of the development of contemporary integrated circuit technology. Due to its low profile, conformal nature, light weight, cheap manufacturing cost, resilient design, compatibility with microwave monolithic integrated circuits (MMICs), and optoelectronic integrated circuit (OEIC) technology, a MSA is ideally suited for wireless communication.

There has been an 80-year history in the field of antenna engineering. An antenna is the main component of a wireless communication network [11]–[17]. With the advent of MIC and high frequency (HF) semi-conductor technologies, microstrip and printed circuit have received the most attention from the antenna community. In the 1950 s, microstrip was initially made available. Nevertheless, this concept had to wait until it was implemented around 20 years after printed circuit board (PCB) technology was first introduced in the 1970 s. Due to their small size, MSA have found use in a variety of fields, including military and civilian applications for missile guidance, RF identification (RFID), broadcast radio, mobile systems, vehicle collision avoidance systems, satellite communications, surveillance systems, direction finding, and radar systems [18]–[22]. The microstrip dimension is hampered by an inherent limited bandwidth disadvantage and poor gain while having several appealing qualities. Researchers working with MSA have discovered a new pattern or set of solutions in which they strive to boost bandwidth by combining various features into the antenna design. Such factors as voltage standing wave ratio (VSWR), return loss, antenna gain, directivity, antenna capacity, and bandwidth are measured. Gain is a metric that gauges how directional the antenna's radiation pattern is. Input power Pi divided by radiated power Pr is known as the ratio. The input power is transformed into surface wave and radiated power, with only a tiny amount of the materials being lost to conductive and dielectric losses.

A graphical depiction of the antenna's radiation qualities, or a mathematical function, that describes the radiation pattern as a function of spatial coordinates. An antenna's efficiency is determined by dividing its input power by the total power it radiates. VSWR=Vmax/Vmin is the formula for the standing wave tension ratio. It would be deceptive between 1 and 2. The ratio of the greatest voltage to the minimum voltage in a standing wave pattern is known as the VSWR. Signal power from a system entering a transmission line results in return loss. The RL as shown in:

$$RL = -20\ log10\ (\Gamma)\ Db$$

The ratio of power radiated into space to total input power, which includes the power lost as a result of conductor loss, dielectric loss, and surface wave radiation, is known as the radiation efficiency. The excitation of the surface wave affects the patch antenna's radiation efficiency in addition to conductor and dielectric losses. The excitation of the surface wave restricts the output because the mutual coupling of components in an array result in unfavourable diffraction of the ground plane's edge, while the influence of the conductive and dielectric losses limits the output as the thickness of the substratum diminishes.

The thicknesses of the substrate and the dielectric constant have a significant impact on the surface wave phase velocity. The frequency range throughout which the antenna's output conforms with a specified standard with regard to some attribute is known as the antenna bandwidth. The frequency range across which the device may be matched to its feed line is defined as the impedance bandwidth of the microstrip patch antenna as the impedance variation with the patch antenna element frequency. A return loss or maximum SWR (measured in terms of the coefficient of input reflection) across a frequency range, often less than 2.0 or 1.5, is a standard way to quantify impedance bandwidth. The frequency range where the radiating power is within 3 dB of the incoming power and essentially has the same radiation pattern is known as the MSA's radiation bandwidth. It is the range of frequencies that the antenna maintains its polarisation through. The main drawback of microstrip patch antennas is their limited bandwidth, however today's wireless communication systems anticipate larger working capacity. One of the key difficulties preventing the widespread deployment of this kind of antenna is the limited bandwidth of printed microstrip patches.

2. PROPOSED ANTENNA DESIGN

To design a microstrip patch antenna following parameters such as dielectric constant (€r), resonant frequency (fo), and height (h) are considered for calculating the length and the width of the patch: i) width of patch (W), ii) effective dielectric constant of antenna (€reff), iii) effective length of antenna, iv) the extended length of antenna (ΔL), and v) the length of the patch. Microstrip patch antennas have certain advantages over conventional microwave antennas. Microstrip patch antennas are renowned for their effectiveness, long-lasting manufacture, and wide range of applications. The features of this microstrip patch antenna are outweighed by its benefits, which include its broad range of applications in a variety of industries, including satellites, medical equipment, and of course, military systems like rockets, aeroplanes, and missiles. The Figure 1 explain microstrip patch antenna.

Antennas used in mobile communication are portable, affordable, and low-profile. Different kinds of MSA have been created for use in mobile communication systems, and microstrip patch antennas suit all requirements. In order to provide the circularly polarised radiation patterns required for satellite communication, either a square patch or a circular patch with one or two feed points may be used. These days, microstrip patch antennas with substrates made of high permittivity sintered material are employed for global positioning system (GPS).

The IEEE 802.16 standard is known as the Wi-Max standard. This might have a 30-mile radius and a 70 Mbps data rate. Marine protected area (MPA) generates three resonant modes at 2, 7, 3, and 5,3 GHz, making it possible to utilise it with worldwide interoperability for microwave access (WiMAX)-compatible networking hardware. Tracking moving things, such as people and automobiles, is possible using radar. The MSA are the best choice for a subsystem with low profile, small weight antennas. A large-scale development of MSA with reproducible output may be done more quickly and at a cheaper cost than with conventional antennas thanks to manufacturing technology based on photolithography.

Telemedicine equipment antenna uses a 2.45 GHz frequency. The wireless body area network (WBAN) architecture is appropriate for wearable MSA. The antenna obtained a higher gain and back ratio compared to the other antennas, which meets the requirement for on-body and off-body applications, in addition to the semi-directional radiation pattern, which is preferred to the omni-directional pattern to mitigate unwanted radiation to the user's body. An antenna that resonates at 2.45 GHz, with a gain of 6.7 dB, and an F/B ratio of 11.7 dB is appropriate for telemedicine applications.

According to research, microwave radiation is the most efficient way to raise body temperature in order to cure dangerous tumours. The specific radiator to be utilised for this function should be built in a rough, manageable, and compact manner. The only radiator that satisfies these requirements is the patch radiator. Dipoles and annular rings printed on the S-band were the basis for the early prototypes of the microstrip radiator that produced hyperthermia. Later, the design was based on the circular microstrip disc at L-band.

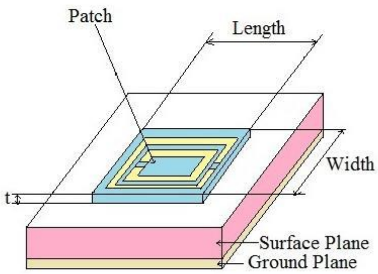

Figure 1. Microstrip patch antenna

3. RESEARCH METHOD

Coaxial feed configuration the outer conductor of a coaxial connection is coupled to the ground plane, while the inner conductor extends through the substratum and is connected to the radiating patch. The feed pin's location is selected to provide the optimum impedance match. Although this device is easy to manufacture, it has poor bandwidth and inaccurate radiation. A high polarised cross will be produced by thicker substrates, which will also raise the surface wave. Edge feed in this design, a conductive stripe is fastened directly to the microstrip patch's edge. This kind of feed setup has the benefit of processing both the patch and the image etch simultaneously, which lowers output.

A ground plane that divides the radiating region is sandwiched between two layers of the substrate material in a configuration known as an aperture coupled. A slot or aperture, which is often cantered beneath the patch, is used in the ground plane to produce coupling between the patch and the feed line. Proximity coupled arrangement. A grounded substratum with a line of feed for microstrips makes up the whole antenna. A microstrip patch is etched on the top surface of the additional dielectric layer that is placed over this material. To address the shortcomings of contacting feed systems, the power from the feed network is electromagnetically connected to the board. The proximity-coupled patch's coupling technique is capacitive, as opposed to the more inductive direct contact methods. A proximity-coupled patch has a wider bandwidth than a straight contact feed patch because the differential in coupling has a significant impact on the impedance bandwidth received.

The electric field oscillation direction of a radio wave as it travels through a medium is the simplest description of polarisation. The first step for determining polarisation is to see the signal from the transmitter's viewpoint. To visualise this, envision yourself standing just behind a radio antenna and looking in the direction it is pointing. If the polarisation is horizontal, then the electric field will move sideways on a horizontal plane. The electric field, on the other hand, oscillates up and down in a vertical plane as a result of vertical polarisation. Linear polarisation refers to an antenna system that employs both horizontal and vertical polarisation. They are orthogonal to one another, the two polarizations. A certain antenna polarisation can only receive on its intended polarisation when it is orthogonal, preventing interference from radiation on the orthogonal polarisation. This is true even when the two orthogonal polarizations are using the same frequency and channel. Instead of being horizontal and vertical, a slant polarisation antenna's polarisation is at -45 degrees and +45 degrees from a reference plane of 0 degrees.

The term "linear" is often used to describe just H/V polarisation antennas, even though this is merely another kind of linear polarisation. When compared to a linear polarisation radio, slant polarisation is equivalent to rotating it 45 degrees while looking in the signal's direction from behind the radio. It is possible to send a signal from the transmitter to the receiver that seems to rotate in polarisation. This is referred to as a circular polarisation (CP). The signal may spin in one of two different ways: right-hand CP (RHCP) or left-hand CP (LHCP). A whole wavelength should not be confused with the 360° rotation the CP signal exhibits in three dimensions. Picture 5 illustrates how phase shifting that result in a CP signal is 90°, or a quarter wavelength offset, when seen from the side of phase-shifted radio waves in two dimensions. Depending on which way the phase shift of 90 degrees occurs, that is, whether H is 90 degrees ahead of V or vice versa, the effect will manifest in three-dimensional space as a spinning signal, either in the left or right-hand direction. The two waves remain linear and orthogonal during the transmission even though the electrical vector of the wave completes a full revolution in a single wavelength.

In essence, a MSA exhibits two polarisation types: linear and circular. Only one direction of electric field variation is visible on the linearly polarised patch. This polarisation may be either vertical or horizontal depending on how the patch is oriented. Variable or unidentified antenna orientation is the main issue with linear polarisation. A desirable alternative to linear polarisation, the circularly polarised patch antenna offers greater flexibility in the angle between transmitting and receiving antennas, lessens the impact of multitrack reflections, improves weather penetration, and enables transmitter mobility and receiving mobility.

To obtain CP in a single feed MSA, many methods have been used. One of the simplest perturbation methods used to obtain CP is the truncate corner of the patch antenna. Building an orthogonal patch with two resonance frequencies and placing the antenna in the middle of the patch will enable CP using this method.

4. RESULTS AND DISCUSSION

The industry-standard modelling technique for simulating full-wave electromagnetic fields in three dimensions is called HF structure simulator (HFSS). E-and H-fields, currents, S-parameters, and tests from nearby and distant radiated fields are all included in HFSS. The success of HFSS as an engineering design tool is largely due to the automated solution process, in which users are only required to provide the geometry, material parameters, and desired performance. For the purpose of automatically fixing the issue, HFSS will provide an efficient, secure, and precise mesh.

The world's top platform for automating electronic architecture for wireless RF, microwave, and high-speed applications is called advanced design system (ADS). ADS developed the first effective and user-friendly guis for the most ground-breaking and commercially successful inventions, including X-parameters and 3D EM simulators, utilised by top firms in the networking, aerospace, and defence sectors. With wireless libraries, circuit-system-EM co-simulation, and an integrated platform for WiMAX, long term evolution (LTE), multi-gigabit per second data connections, radar, and satellite applications, ADS delivers comprehensive, standard-based design and testing.

A specific tool called CST microwave studio (CST MWS) is used to simulate HF components using 3D electromagnetic (EM). With its exceptional performance, CST MWS has become the top option for research and development (R&D) departments that are at the forefront of technology. CST MWS makes it possible to quickly and accurately evaluate HF components such antennas, filters, couplers, planar and multi-layer structures, as well as SI and compatibility (EMC) effects.

Some advantages ard discussed is, i) lightweight, ii) diminutive, iii) low profile, iv) necessary cavity backing, v) polarization, both linear and circular, vi) operation on dual and triple frequency, and vii) matching and feedline network construction is simultaneous. Some disadvantages ard discussed is, i) poor performance, ii) small gain, iii) significant ohmic loss in array feed structures, iv) limited power handling capability, v) surface wave excitation, vi) polarization purity is difficult to attain, and vii) high performance arrays are required for complex feed arrangements. Due to its relevance is an active microstrip patch antenna research field for various journal publications in the year of 2010–2020 is shown in Table 1 and its comparison chart publication in 2010–2020 is shown in Figure 2. Due to its relevance is an active microstrip patch antenna research field for various parameters is shown in Table 2 and its comparison chart publication in 2010–2020 is shown in Figure 3.

Table 1. Details of microstrip patch antennas

Sl. No	Year	Conference	High quality journals
1	2010	150	120
2	2011	250	180
3	2012	280	250
4	2013	350	280
5	2014	380	320
6	2015	420	380
7	2016	580	400
8	2017	620	480
9	2018	680	520
10	2019	700	600
11	2020	800	620

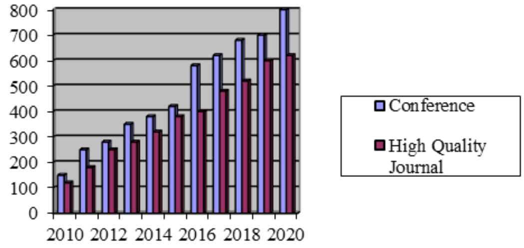

Figure 2. Comparison chart for published paper in conference and journal (based Table 1)

Table 2. Performance analysis of return loss, gain and VSWR

Sl. No	Frequencies (GHz)	Return loss (dB)	Gain (dB)	VSWR
1	2.5	-35.05	9.2	1.8
2	3.5	-32.08	8.5	1.7
3	4.5	-30.25	8.3	1.6
4	5.5	-28.25	7.8	1.8
5	6.5	-25.45	7.5	1.6
6	7.5	-22.45	7.2	1.5
7	8.5	-20.48	8.5	1.4
8	9.5	-19.05	7.8	1.5
9	10.5	-18.05	8.2	1.3
10	11.5	-17.15	6.5	1.2
11	12.5	-16.20	5.5	1.4

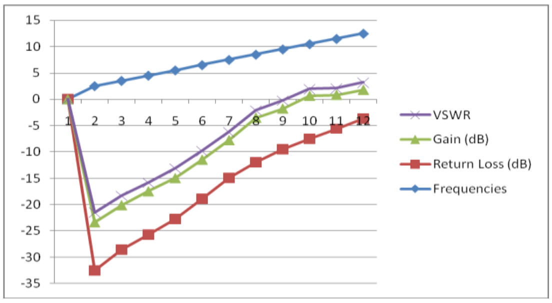

Figure 3. Comparison chart for published paper in conference and journal (based Table 2)

5. CONCLUSION

The technical developments in the area of microstrip patch antennas are examined in this article. MSA are becoming more and more technologically every day. The MSA is now the subject of extensive research for potential uses. The bulk of approaches are developed by coordinating the bandwidth and strength of the MSA. According to the study, there were not many publications on the MSA in the early years, but after that, the number increased until the years 2010–2020, after which there was a steady decline in the number of publications. Many pieces of software have been created to emulate MSA.

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