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Performance analysis of microstrip patch antenna for wireless communication systems

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ABSTRACT

An antenna may be thought of as a temporary tool that directs radio waves for transmission or reception. Aside from being inexpensive, small, easy to manufacture, and compatible with integrated electronics, the microstrip patch antenna (MPA) offers several other benefits as well. These two methods are often seen as low-cost, adaptable, dependable, high-speed data connection choices that promote user mobility. An overview of how MPA have been used throughout the last several decades is provided in this article. It has been suggested that there are many approaches to enhance the performance of MPA, including the use of composite antennas, highly integrated antenna/array and feeding networks, operating at relatively high frequencies, and using cutting-edge manufacturing methods. Dual or multiband antennas are essential for meeting the demands of wireless services in this rapidly evolving wireless communication environment. Here is an overview of the patch antenna literature for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications.

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1. INTRODUCTION

The past fifteen years have seen the development of microstrip antenna (MSA) technology as a well-known trend in the antenna industry. Over this time, MSA and arrays have been the focus of more than 1,500 research articles, several books, symposium sessions, and short courses. Due to their compact profile, microstrip patch antenna (MPA) are often used; nevertheless, they also have a number of drawbacks, including lower gain and a smaller bandwidth. The several techniques used to boost the gain and widen the bandwidth are summarised below. The technological field of wireless communication that is generating the greatest discussion regarding social life in the twenty-first century. Numerous households, offices, and academic institutions use contemporary wireless local area network (WLAN). The Hertz (dipole) antenna is the first well-known antenna experiment in 1886. Then developed a radiotelegraph method and produced and commercialised wireless technology using monopole antennas (at a quarterwave wavelength). The original idea for a MSA was put out by Deschamps in 1952 [1]–[5].

The idea of MSA wasn't really put into practice until the late 1970s. The low profile, light weight, simplicity of production, and adaptability to mounting hosts are appealing qualities of MSA. Two parallel conducting layers, a thin dielectric substrate, and additional parts make up a sandwich that is a microstrip device. The resonant forms of the top conductor patch and the bottom conductor ground plane are both simple. An antenna is a wireless communication system's primary building block. An antenna is a device that converts a radio frequency (RF) signal passing via a conductor into an electromagnetic wave circling the earth. An antenna will radiate in a certain pattern into space when a signal is delivered into it. The effectiveness of an antenna may be influenced by a number of factors, including beamwidth, side lobes, polarisation, input impedance, return loss, bandwidth, directivity, gain, and others. The part of personal communications systems that has been ignored the most up to this point is the antenna. However, the way radio frequency energy is dispersed into and gathered from space has a significant influence on how effectively spectrum is utilised, how costly it is to establish new personal communications networks, and how well-performing such networks are. The characteristics of an antenna, most notably its physical appearance, might alter depending on its use. The many kinds of antennas available today each have a specific purpose. Each system must consist of a variety of small, effective parts. A common component is the MPA because of its small size [6]–[10].

Low profile antennas, such as the microstrip or patch, provide a variety of benefits over other types of antennas. Due to its compact size, MSA are used in a variety of sectors. A patch antenna has certain disadvantages, much as a coin has two sides. In patch antennas, the bandwidth and gain-the two key antenna characteristics-are restricted. Although there are several approaches to solving this issue, each one poses new issues that need more consideration. Applications have been created that were previously only possible a few decades ago, thanks to the rapid growth of information technology and wireless communications. Our daily lives now heavily rely on interpersonal ties. Almost everything nowadays is wireless and portable. While other components should be mostly insulated from their surroundings, an antenna should successfully radiate in the appropriate direction to free space. With greater capability, a device requires an increasing variety of wireless communication protocols. Either equipment would need to be able to accept a rising number of antennas, or the bandwidth of the current antennas would need to be significantly increased. There are greater space constraints in the locations where antennas are utilised as a result of the shrinking size of devices [11]–[15]. Additionally, MSA production use printed-circuit technology, allowing low-cost mass production. Many traditional antennas are being replaced by MSAs in both commercial and military applications. The types of applications that may be deployed using MSAs are nonetheless limited by their innately low bandwidth. Consequently, the main objective of this paper's inquiry has been to increase the bandwidth of the MSA.

2. MICROSTRIP PATCH ANTENNA

The MSA is regarded as the most innovative area of antenna engineering due to its low cost of materials and simple production method, which may be carried out inside of research institutes or universities. The concept of an MSA with a conducting patch on a ground plane divided by a dielectric substrate was not taken into consideration prior to the introduction of large-scale integration and the consequent reduction of electronic circuits in 1970. The literature review on MSA is covered in this part. For worldwide interoperability for microwave access (WiMax) applications, it has been proposed to develop stacked, little slotted antennas with improved bandwidth. In this research, the top patch has a rectangular slot, while the lower patch has an asymmetric U-slot. This effort seeks to lower the size of an MPA by enlarging the path that the surface current traverses by carving a slot in the radiating patch. Applications for WiMax have shown their ability to use antenna in the frequencies of 3.40-3.69 GHz and 5.25-5.85 GHz [8]. A microstrip E-shaped patch antenna has been proposed as a solution for wireless applications. The antenna may change from right hand circular polarisation (RHCP) to left hand circular polarisation (LHCP) and back again. With a maximum gain of 8.7 dBic at 2.45 GHz and an effective bandwidth of 7%, the antenna design offers a high gain.

In L band satellite systems, it is advised to utilise a MPA [16]–[20] with a parasitic ring slot. For application in RF and wireless systems, a rectangular L-shaped MPA has been designed. The employment of capacitive coupled four-probe feeds and coplanar parasitic ring slot patches to increase the impedance and CP bandwidths, respectively, is its key feature. Two pairs of small L slots placed on a rectangular patch parallel to the non-radiating edge improve the impedance bandwidth. It is thus possible to operate at two frequencies. The 1.30 MHz to 1.45 GHz impedance bandwidth of this circuit. The operation of antennas is based on electromagnetic waves. MSA are used in many practical applications because they have several benefits over conventional microwave antenna. An MSA fundamental structure is composed of a ground plane and a radiating patch on opposite sides of a dielectric substrate (r10). For the purpose of creating an MPA, a conducting (metallic patch on a thin, grounded dielectric substrate) patch of any non-planar or planar shape is put on one side of a dielectric substrate. It is a printed resonant antenna for semi-hemispherical coverage narrow-band microwave wireless networks. The extensive use of microstrip technology is a result of the flat shape of the MPA and the ease of microstrip technology integration. Patch MSA come in two basic and often used shapes: rectangular and circular. The influence of the dielectric constant, substrate thickness, strip width, and impedance on the characteristic impedance of the microstrip line is discussed.

Utilising multiple broadcast and multiple receive antennas is one of the fundamental advancements in next-generation wireless communication technology. Multiple input multiple output (MIMO), which uses multiple antennas at the transmitter and receiver, is predicted to significantly improve the performance of future wireless broadband data systems. MIMO technology's enhanced spectral efficiency, less fading, and potential to dramatically increase data speed and connection range without the need for extra capacity or transmit power have all been noted in wireless communications. All currently used wireless communication protocols, including IEEE 802.11n (Wi-Fi), IEEE 802.16e (WiMAX), 3rd generation partnership project (3GPP) long term evolution (LTE), 3GPP high-speed packet access evolution (HSPA+), and upcoming fourth generation (4G) and the fifth generation (5G) systems, heavily depend on MIMO because of these features. The technical field that is growing the fastest is wideband MIMO systems based on MPA because of their exceptional spectral efficiency. Over the next 10 years, interference and spectral efficiency will be the two main problems in wireless communications. The utilisation of the spectrum will be hampered by wireless internet, mobile data and video transmission, and other considerations. Spectrum abuse will affect other services negatively, just as it does now. Methods for interference-reduction should be employed since the main goal is to increase spectral efficiency. MIMO systems, which supposedly exploit remarkable spectrum efficiency, offer very high data speeds. We show how MIMO systems are designed using MSA and how they function in the present wireless environment.

These antennas are incompatible with the high data rate wireless networks of today because of their limited bandwidth. A special kind of electrical transmission line called a microstrip is used for microwave frequency communications, and it may be built using printed circuit board (PCB). Due of the antennas' closer proximity, mutual coupling is another critical issue that severely reduces MIMO systems' performance [20]–[26]. The ground plane is separated from the conducting strip by a dielectric layer that resembles a substrate. An MPA is a conducting patch with a ground plane on the other side of a dielectric substrate. It may be configured in either a planar or non-planar manner. This printed resonant antenna is a popular choice for narrow-band microwave wireless networks that need semi hemispheric coverage. Because of its planar structure and ease of integration with microstrip technology, the MPA has received a great deal of attention and is often used as a part of an array. There has been a lot of study done so far on MPA. The geometries are listed in full and their main attributes are briefly described. Patch MSA come in two basic and often used shapes: rectangular and circular. Both the simplest and most complicated programmes benefit from these changes. Patch MSA come in two basic and often used shapes: rectangular and circular. Both the simplest and most complicated programmes benefit from these changes. These small antennas may be made to stick to both flat and curved surfaces. They are now physically robust when installed on rigid surfaces, simple to build, compatible with microwave monolithic integrated circuit (MMIC) designs, and extremely versatile when the proper patch form and mode are selected. All thanks to modern printed-circuit fabrication processes.

3. CHALLENGES OF MICROSTRIP PATCH ANTENNA

One of these antennas' biggest flaws is their limited bandwidth. The obvious solution to improve bandwidth is to thicken the substrate, but doing so has the substantial drawback of reducing efficiency since the antenna can radiate less power because a significant amount of the input power is wasted in the resistor. Although decreasing the structure height may seem like a smart idea, it may result in a smaller impedance bandwidth and less efficient radiation. This compromise is often made while trying to maintain performance standards while designing small antennas. Wide-impedance bandwidths for MSA have been created using a number of unique techniques. High permittivity substrates are sometimes used for MPA, even though they are not the ideal option for an antenna's bandwidth. For substrates with low dielectric constants, a portion of the overall power available for direct radiation is trapped along the surface. The three-dielectric layer substrate is utilised in place of this single-pin-shorted substrate to increase radiation efficiency and bandwidth without compromising cost and operational benefits.

The microwave world has lately been quite interested in another use of electromagnetic band gap (EBG) structures due to their distinct properties. The feed line between the two patches of a twin array patch antenna is efficiently carved with EBG patterns that prevent the transmission of any electromagnetic surface waves within the band gap. This allows for further control of electromagnetic wave behaviour in addition to the typical directing and/or filtering components. With a 48.8% increase in bandwidth, these tiny, unassuming false EBG patterns provide a huge bandwidth improvement. Since the radiating patch does not need to be changed in order to use an impedance matching circuit, impedance matching keeps the radiation qualities. The patch substrate selection is another factor that is unrelated to the use of the IM method. It is also possible to design slots in MSA utilising the ground plane's L, U, T, and inverted T slots to achieve ultra wideband. Typical omnidirectional microwave antennas have slots in them.

The use of a single, almost rectangular microstrip radiator reactively loaded with an active negative capacitor and composite-resonator MSA with high gain and broad bandwidth allows for the insertion of an unpaired negative capacitor and an unpaired inductor. The low gain of conventional MSA components presents similar challenges. Topology optimisation is the most generic term for design optimisation techniques in which both the connections and the shapes of individual device pieces are subject to design. One example of this is the topology of twin patch antenna arrays. The most popular method for topology optimisation is called the material distribution strategy. It divides the design domain into small pieces that, when put together, provide a representation of the device. Contrary to typical MSA, the capillary backing technology has been used to increase gain while removing the bidirectional radiation pattern. Another technique to improve is to cover the lenses with something. The conventional lenses-elliptical, hyper-hemispherical, and extended hemispherical, for example-focus the radiation beam from the radiator components. Since it combines microstrip radiator components with a dielectric lens, the integrated microstrip lens antenna may be thought of as a composite antenna. This makes it very useful for high frequencies (mm, sub-mm, terahertz (THz), and optical waves) applications. Multi-layer dielectric substrate: partial substrate removal it is also well known that gain may be increased by using an antenna array.

Since the operating frequencies are correlated with the electrical size of the antenna, the final restriction of traditional MSA is reduction of the relatively large size, especially at lower microwave frequencies. The previous limitation is comparable to this one. In general, the rectangular microstrip antenna (RMSPA) should match a half-guided wavelength. In response to the increased need for wireless communication devices that are ever-smaller, several attempts have been undertaken to reduce antenna size and produce the electrically tiny MSA.

Effectively shrinking MSA is possible by employing inductive or capacitive loading. By employing composite metamaterial resonators, the size of the MSA may be reduced. Bandwidth may be enhanced by modifying the radiating patch's form. It has been shown that certain patch shapes have lower Q factors and greater bandwidth than others. These patches come in a variety of forms, such as an annular ring, a rectangular or square ring, a shorted patch, and others. Broadband MPA may accommodate tailored patches in a variety of combinations. This antenna works with C-band.

The FR-4 substrate of this antenna has a bandwidth of 13.58% when compared to a standard circular patch antenna. With the same radius, the suggested antenna performs better than a typical circular patch antenna. T-slot is an additional design for changed from patches. Patch antenna with a rectangular shape for broadband. This particular MSA arrangement contains multiple resonators close to one another; only one of them is fed, while the rest are parasitically coupled-this is sometimes referred to as gap coupling. Another option for feeding multiresonator configurations is to directly link the patches using microstrip line. In certain circumstances, hybrid coupling uses both gap and direct coupling. Shifted parasitically coupled planar multiresonator design to broaden MSA. This technique takes use of a wideband, parasitically coupled planar multi-resonator antenna.

The results reveal a progressive increase in resonance frequency from 2.989 GHz for the reference patch to 3.023 GHz for anticlockwise shifted parasitically linked components. The impedance bandwidth also gradually increases from 65 MHz to 251 MHz (about four times) over time. It is suggested to use a gap-coupled planar T-slot wide band rectangular patch antenna for a multiresonator broadband MPA. It is possible to get a gain of up to 9.88 dBi at a -10 dB return loss, a bandwidth of 25.23% impedance, and an average gain of around 7.43 dBi across the passband. A single-layer, single-patch wideband MSA has a U-shaped slot as part of its design. The U-shaped slot with a thick air substrate of 12 mm provides enhanced bandwidth and achieves an impedance bandwidth of 500 MHz or 27.5% at the center frequency of 1815 MHz (at 10 dB return loss). The antenna's performance analysis is shown in Table 1.

Table 1. Performance analysis of MSA

Frequencies (GHz) [10]–[15]	Return loss (dB) [10]–[15]	Gain (dB) [10]–[15]	voltage standing wave ratio (VSWR) [10]–[15]	Efficiency (%) [10]–[15]
2.8	-15.25	2.2	1.2	40
3.8	-18.25	3.2	1.3	45
4.8	-19.25	4.2	1.4	50
5.8	-20.56	4.8	1.5	52
6.8	-22.59	5.2	1.6	60
7.8	-25.89	6.2	1.7	70
8.8	-28.56	7.2	1.8	75

4. CONCLUSION

MSA are widely used because to their clear benefits, but they also have some clear drawbacks, such as poor gain, a limited bandwidth, and a bigger footprint. Based on earlier studies on MSA, a few more areas for improvement are identified in this work with respect to these restrictions. Utilising various MSA topologies, the creation of composite antennas based on MSA, and better manufacturing processes for MSA may eliminate these limitations while concurrently balancing all three characteristics. For a variety of applications, this article offers an overview of MSA as well as the most current advancements in MPA. It is plainly clear from this study that various initiatives are being made to get around some of the drawbacks of traditional MSA characteristics. This article analyses theoretically MPA. It was discovered after analysing a number of research investigations that slotted patches and array topologies may help overcome decreased gain and confined power handling capacity. We examine a number of feeding process components as well as different antenna characteristics. For each application, a bespoke MPA may be created, and this antenna offers a number of advantages over more traditional microwave antennas.

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