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Compact Microstrip Patch Antenna Design for Wireless Applications: A Review

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ABSTRACT-

Rapid advances in wireless communications in recent years have led to the development of many portable wireless devices such as wireless sensors, smart cell phones, IoT devices, wearable devices, and GPS receivers. This paper describes different types of feeding techniques applied to microstrip patch antenna, which is one of the important aspects. A good impedance matching positioning element depends largely on the feeding techniques used. After describing the different feeding techniques, the paper gives a better understanding of the design parameters of the antenna and their effect on bandwidth and gain. An antenna is a device that transmits and/or receives electromagnetic waves.

KEYWORDS - Microstrip Patch Antenna; Wireless; Feeding Method.

1. INTRODUCTION

Wireless communication systems have evolved rapidly over the past decades and have already had a dramatic impact on human life. In the past few years, the development of Wireless Local Area Networks (WLAN) represents one of the major interests in the information and communications sector. Thus, in commercial and government communication systems, there is a need to develop low cost, minimum weight and low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies.

The most popular methods to analyze patch microstrip antennas are the transmission line model, the cavity model, and the full wave model (mainly including the integral/transient method). The power line model is the simplest and provides good physical understanding, but is less accurate. Microstrip antennas have the advantages of small size, low profile and light weight, adaptable to flat and non-flat surfaces. Very less amount of structure is required while assembling it. These are simple and inexpensive to manufacture using modern printed circuit technology. However, patch antennas have drawbacks. The main disadvantages of microstrip antennas are: low efficiency, narrow bandwidth of less than 5%, low RF power due to small separation between the radiation patch and the ground plane (not suitable for high power applications. Model cavity models are very accurate and physics provide a good understanding of, but are complex in nature. Full-wave models are extremely accurate, versatile, and can handle single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements, and intersections.

Microstrip patch antennas have various advantages such as low profile, light weight, easy fabrication and size reduction to suit mounting hosts and bandwidth enhancement are major design considerations for practical applications of microstrip antennas. A number of numerical methods have been developed by various researchers to ease the computational efforts when designing microstrip patch antennas, including MoM based method. MoM involves the use of Sommerfeld-type integrals to solve the dielectric slab Green's function. Comparisons have been made between different feeding techniques. Finally, a microstrip patch antenna at the specific frequency i.e. 1.25 GHz has been designed and simulated on the design software for a better understanding of the design parameters of the antenna and their effect on the bandwidth and gain pattern.

In a basic aperture coupled patch antenna the radiating microstrip patch element is etched on the top of the antenna substrate, and the microstrip feed line is etched on the bottom of the feed substrate. Thus the thickness and dielectric constant of these two substrates can be independently chosen to optimize the specific electrical functions of the radiation and circuitry. Although the original prototype antenna used a circular coupling aperture, it was quickly realized that the use of a rectangular slot would improve the coupling, for a given aperture area, due to its increased magnetic polarization capability. Aperture coupled microstrip antennas involve more than a dozen material and dimensional parameters, and we summarize the basic trends with variation of these parameters below: antenna substrate dielectric constant, antenna substrate thickness, microstrip patch length, microstrip patch width , feed substrate dielectric constant, feed substrate thickness, slot length, slot width, feed line width, position of the feed line relative to the slot, position of the patch relative to the slot.

2. LITERATURE SURVEY

N. Chiba, T. Amano and H. Iwasaki (2015), this technological trend has focused on the design of micro-strip antennas with simple geometry. Patch antennas offer several benefits that are not typically exhibited in any other type of antenna configuration. Microstrip antennas are simple and inexpensive to fabricate using printed circuit board technology. He has a very low profile and low weight. They are compatible with microwave and millimeter-wave integrated circuits, and have the ability to conform to planar and non-planar surfaces. Furthermore, once the patch size and operating mode are selected, designs become very versatile in terms of operating frequency, polarization pattern, and impedance.

Neha Parmar (2014), The low efficiency, high value of Q, poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth of microstrip patch antennas have reduced their versatility. But in some applications where narrow bandwidth is desirable, such as government security systems, microstrip patch antennas are watertight. **R. Saluja (2017),** the thickness of the dielectric material, the desired microstrip antenna can have large bandwidth (up to 90 percent) and good efficiency (up to about 35 percent). But when the height of the dielectric material increases there is some power loss due to surface wave. However, there are some methods like cavity method and stacking as well as other method are used to reduce surface ripple and hence power loss while maintaining large bandwidth and good efficiency. Additionally, both linear and circular polarization of a rectangular microstrip patch antenna increases their versatility.

R.A Sainati, (2018), The patch operated microstrip antenna (MSA) on ground substrate was underdeveloped before the revolution of electronic circuit miniaturization and large-scale integration in wireless communications (i.e. 1970). Since then the radiation from the radiation patch of microstrip antenna with different configurations has been studied by many researchers. Munson's early work was a low profile flush mounted microstrip antenna for practical rocket and missile applications. Multiband frequency mode operation can be achieved by using multilayer structures due to the high demand in slow communications. **S.A. Long and M.D. Walton (2019),**Various mathematical models were also developed to increase the area of this antenna. The papers or articles published in magazines on these antennas in the last ten years show the importance they have acquired. It is the most preferred choice for present day antenna designers to design micro strip antennas. In this section the literature survey on microstrip antenna is discussed.

Shagun Maheshwari, Priyanka Jain, Archana Agarwal (2019), A couple line feed into a rectangular patch antenna is described by Van et al. Large bandwidth antenna is achieved which is 2.5 times greater than that of ordinary edge fed patch antenna. Additionally antennas with reduced physical dimensions are achieved from previously available research while maintaining their large output. Chiba et al. A dual-frequency planar antenna was introduced for the handset. The author describes an outer quarter-wavelength annular-ring with a short-circuit plane for the low resonance frequency and an inner quarter-wavelength rectangular patch of a dual-band antenna for the high frequency response. Mark et al. An L probe feed rectangular microstrip patch antenna was proposed for WLAN applications. In this paper the authors have achieved 36% impedance bandwidth and approximately 7-dBI average gain by introducing an attractive L-shaped probe feed to a thick microstrip antenna. **Y. S. H. Khraisat (2022),** Here the design of the broad-band-slot patch antenna on the microwave substrate has resulted in increased thickness of the desired antenna compared to the case with foam material. But the measured resonant frequencies and far-field patterns are well compared to previous measured data and the desired antenna gain is about 6.5 dB. The authors have used a U-slot circular patch antenna with L-probe feeding and also used a foam substrate which is presented by Guo et al. Hence there is more bandwidth gained i.e. about 15% compared to using U-slot alone and about 14% compared to using L-probe alone.

Table 1 Comparison of literature survey

Sr. No.	Author	Year	Work Outcome
1.	**N. Chiba, T. Amano and H. Iwasaki**	2015	This technological trend has focused on the design of micro-strip antennas with simple geometry. They are compatible with microwave and millimeter-wave integrated circuits, and have the ability to conform to planar and non-planar surfaces.
2.	**Neha Parmar**	2014	The height of the dielectric material increases there is some power loss due to surface wave. The low efficiency, high value of Q, poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth of microstrip patch antennas have reduced their versatility.
3.	**Saluja**	2017	Depending on the thickness of the dielectric material, the desired microstrip antenna can have large bandwidth (up to 90 percent) and good efficiency (up to about 35 percent). Additionally, both linear and circular polarization of rectangular microstrip patch antennas increases their versatility.
4.	**R.A Sainati,**	2018	Microstrip antenna (MSA) on ground substrate was underdeveloped before the revolution of electronic circuit miniaturization and large-scale integration in wireless communications. Multiband frequency mode operation can be achieved by using multilayer structures due to the high demand in slow communications.
5.	**S.A. Long and M.D. Walton**	2019	Various mathematical models were also developed to increase the area of this antenna. Papers or articles published in magazines on these antennas in the last ten years show how much importance they have gained.

6.	**Shagun Maheshwari, Priyanka Jain, Archana Agarwal**	2019	A couple line feed into a rectangular patch antenna is described by Van et al. Large bandwidth antenna is achieved which is 2.5 times higher than that of ordinary edge fed patch antenna. Additionally, antennas with reduced physical dimensions are derived from already available research while maintaining their large output.
7.	**S. H. Khraisat**	2022	The authors have used a U-slot circular patch antenna with L-probe feeding and also used a foam substrate. Therefore approximately 15% more bandwidth is achieved than using the U-slot alone and approximately 14% more than using the L-probe alone.

3. ADVANTAGES of Microstrip Patch Antenna

1. Microstrip feed lines are easy to create, easy to match by controlling inset position, and easy to model. However as substrate thickness increases, surface waves and spurious feed radiation increase, which limits the bandwidth for practical designs.
2. Microstrip antennas are relatively inexpensive to manufacture and design due to the simple 2-dimensional physical geometry. They are commonly employed at UHF and higher frequencies because the antenna size is directly related to the wavelength at the resonant frequency.

4. METHODS

There are many methods of analyzing microstrip antennas; the most popular are the transmission line (where we assume the patch is a transmission line or part of a transmission line). The second method is the cavity mode (here we assume that the patch is a cavity loaded with dielectric). The transmission line method is the easiest way to study microstrip patch antennas. The transmission line method is the easiest way to study the microstrip antenna. In this method, the transmission line model represents the microstrip patch antenna by two slots, separated by a low impedance transmission line of length L. The results obtained are not the most accurate compared to other methods, but they are good enough.

4.1 FEED METHODS

There are mainly four basic methods for the feeding to these antennas

Probe Coupling Method

Microstrip Line Feeding Method

Aperture Coupled Microstrip Feed Method

Proximity Coupling Method

4.1.1 PROBE COUPLING METHOD

Coupling power to a microstrip patch antenna can be done in a flip-flop fashion. The inner conductor of the test line is connected to the ground connection through a groove in the ground plane and in the substrate material. Simplicity of design and correction of installation disturbances by positioning the feed make this feed method popular. But there are other limitations such as larger lead for thicker substrate, difficulty in soldering matrix elements, etc.

4.2 MICROSTRIP LINE FEEDING METHOD

This method is very easy to design and implement. But this process faces some limitations. If the substrate thickness is increased in the design, surface waves and spurious radiation also increase. As a result, unwanted cross-polarizing radiation appears. Microstrip feed can be used in situations where antenna performance is not a big issue. Edge coupled feeds can be enhanced with coplanar waveguide feeds.

4.1.3 PROXIMITY COUPLED METHOD

Typically, in this configuration, the microstrip line will be placed on the bottom substrate and the patch feature will be placed on the top substrate. Another name for this diet is magnetically bonded foods. A strong environment will appear between the power line and the patch in this case. Choosing a thin substrate layer and placing a patch on the top layer will improve bandwidth and reduce spurious radiation. Executing this feed is difficult due to problems with the alignment of the feed and the part in the right place. A peaceful thing is soldering, and related problems can be eliminated.

4.1.4 APERTURE COUPLED FEED METHOD

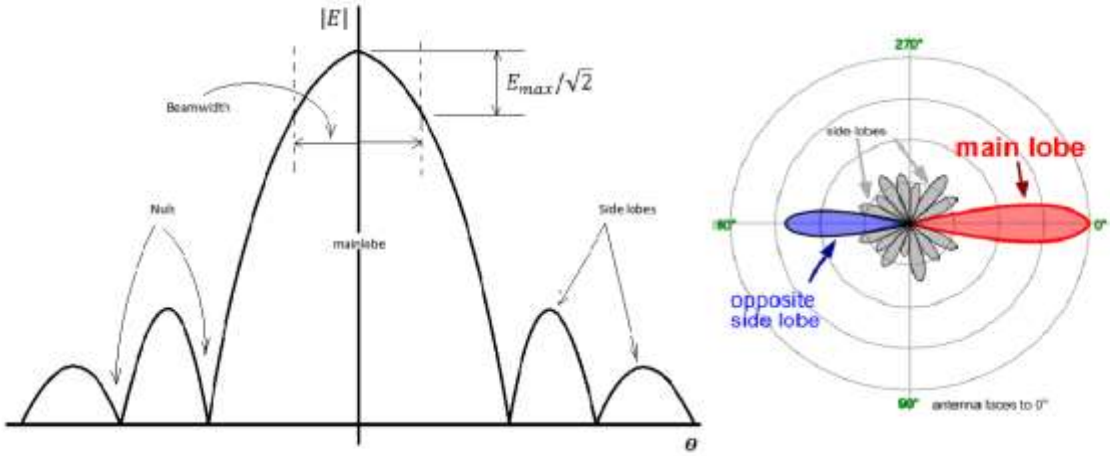
The hole will be placed on the ground plane and the feedline will be placed on the bottom substrate. This will be magnetically connected to the surface substrate through the ground plane surface. Care must be taken with substrate parameters and properly selected power configuration and operation independent of potential radiation. The mating groove should be almost submerged in water so that the magnetic field of the patch is large.

4.2. PARAMETERS

4.2.1 RADIATION PATTERN

We are interested in determining and measuring the electromagnetic wave intensity at a remote location, which is represented by the radiation pattern that emanates from an antenna. This distant point is at a point in space where the wave is thought to be flat and oriented normal to the antenna. The two field components of the radiation pattern are a field vector and a field vector. The radiation pattern is the variation of the electric field as a function of angle. Cartesian coordinates or polar coordinates can be used to depict the radiation pattern. More antenna characteristics related to microstrip patch antennas, including radiation pattern, efficiency, quality factor, directivity, gain, and more, will be covered in later sections of this work.

Figure 1 Radiation pattern; cartesian and polar diagram



4.2.2 DIRECTIONAL ANTENNAS

Speaking of omnidirectional antennas that radiate in all directions is synonymous with the term dipole antenna. An additional type of antenna is directed antennas. A directional antenna is one that emits power in a single, concentrated direction. like in microwave communications, directional antennas can be fixed in a particular spot and pointed in the direction of the receiver (or broadcaster); like in radar, they may need capabilities for rotation. Antenna quality is determined by the antenna's ability to concentrate power in one direction more than in others. This ability is commonly described by terms like gain, directivity, front-to-back ratio, half-power HPBW beamwidth, and many more. as well as antenna specifications. We'll talk about these characteristics later.

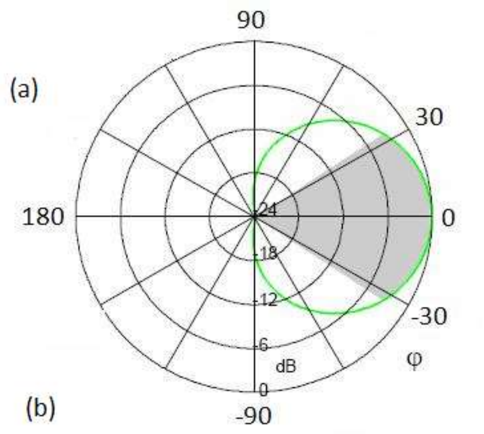


Figure 2 Radiation pattern of a typical directional antenna

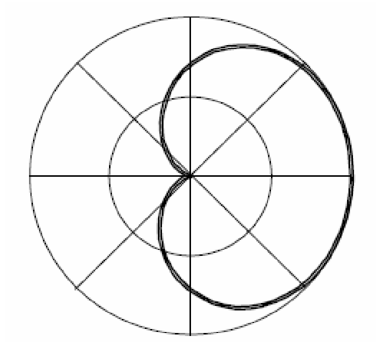


Figure 3 Radiation pattern of a simple directional antenna

We can achieve the required radiation pattern by combining two or more components to create an antenna with a given distance and determined phase changes. This technique is used by the Yagi-Uda antenna, a particularly popular type of antenna. Most households have the capability to receive both VHF and UHF TV transmissions. The Yagi-Uda antenna operates on the radiation coupling principle, which states that when power is applied to one element, it will cause other components to become active.

4.2.3 EFFICIENCY AND QUALITY FACTOR

For a microstrip antenna, the efficiency can be defined as the power radiated from the microstrip element divided by the power received by the input of the element. Factors that affect antenna efficiency and make it high or low are dielectric loss, conductor loss, reflected power (Voltage Standing Wave Ratio VSWR), cross polarization loss, and power dissipated in any loads on the element.

4.2.4 DIRECTIVITY AND GAIN

Directivity is the ability of an antenna to focus energy in a specific direction. The definition of directivity according to the IEEE 145-1983 standard: “Directivity (of an antenna) (in a given direction) is the ratio of the radiation intensity in a given direction of the antenna to the average radiation intensity over all directions”. The directivity is always greater than one.

4.2.5 POLARIZATIONS

Polarization can be classified as linear, circular and elliptical. In linear polarization the antenna radiates power in the plane of propagation, only one plane, the antenna is polarized vertically linear when the electric field is perpendicular to the earth's surface and polarized horizontally linear when the electric field is parallel to the earth's surface. The circularly polarized antenna radiates power in all planes in the direction of propagation (vertical, horizontal and in between). The plane of propagation rotates in a circle making a complete cycle in one wave period. Return loss is an important parameter when testing an antenna. It is related to impedance matching and maximum power transfer theory. It is also a measure of an antenna's effectiveness in delivering power from the source to the antenna.

5. COMPARISONS

We have studied that capacitively coupled antenna have more bandwidth as compared to aperture coupled antenna at a specific frequency of 1.25 GHz and have more gain as shown in Table 1.

Table 2 Comparisons of different parameters

Frequency (GHz)	Slot length (cm)	Stub length (cm)	Real S(1,1)	Imaginary S(1,1)	Z (dB)
2.25	0.9	2	-0.5813	5.73e04	-4.71
2.25	1	2	-0.3677	0.1689	-7.86
2.25	1.2	2	-0.4057	-0.4379	-4.48
2.25	1.12	0.4	0.7977	0.4863	-7.95
2.25	1.12	0.8	0.4765	0.6675	-1.93
2.25	1.12	1.8	-0.1791	-0.4836	5.10

6. CONCLUSIONS

In this section we will discuss the response of aperture coupled microstrip antenna to various parameters. The antenna structure is analyzed using CST software based model with different input parameters. Comparative studies of different configurations of feeding techniques have concluded that the capacitively coupled microstrip antenna provides a bandwidth reduction of approximately 20%. The comparison and simulated results are also compared to measurements from the fabricated hardware. All three designs of feeding techniques achieved the best return loss in the desired frequency region, which is 1.25 GHz.

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