Slot Based Microstrip Antennas for Dual Band WLAN Applications

(Thesis submitted towards the partial fulfillment of requirement for the award of degree of)

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CERTIFICATE

I , Ruchi, hereby certify that the thesis report entitled **"Slot based microstrip antennas for dual band WLAN applications"** is an authentic record of my study carried out as requirements for the award of degree M.E(Electronics &communication Engineering) at Thapar University, Patiala, under the guidance of **Dr. Rajesh Khanna** and referred other researcher's work which are duly listed in the reference section.

The matter presented in this report has not been submitted to any other University/Institute for the award of Master of Engineering.

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This is certified that the above statement made by the student is correct to the best of my knowledge and belief.

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ABSTRACT

The field of mobile and wireless communication is growing at very fast rate covering many technical areas. Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) technology is most rapidly growing area in the modern wireless communication. This gives users the mobility to move around within a broad coverage area and still be connected to the network. This provides greatly increased freedom and flexibility. For the home user, wireless has become popular due to ease of installation, and location freedom. Among wireless devices antenna is quite important component. So, there is continuously increasing requirements of efficient and high performance antenna. The features of antenna which every technology requires are light weight, small in size and low cost etc. Another important desired properties of antenna are wide bandwidth and resonant at multiple frequency.

Next Generation devices have also more than one application embedded in single device so antenna supporting more than one band is required and multiband operation of antenna is another challenge. Almost all these requirements can be fulfilled by Microstrip patch antenna.

The main objective of this report is to design Coaxial Fed Dual band Microstrip antennas for WLAN applications using three different shapes of patch that are rectangular, triangular and pentagonal. The designed antennas resonate at two frequencies 2.4GHz and 5.2GHz. The bandwidth is also increased upto a sufficient level by having slots in the patches. The various parameters like return loss, smith chart, gain, radiation pattern and bandwidth have been studied and plotted for each simulated antenna. The parametric study of each of the designed antenna is also done. The simulated results of the effect of the various parameters like length of the patch, location of the feed point and position of the slot are also shown.

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List of Abbreviations

CAD	Computer Aided Design
CPW	Coplanar Waveguide
CST	Computer simulation technology
DCS	Digital Communication System
DRA	Dielectric Resonator Antenna
GHz	Giga Hertz
GSM	Global system for mobile communication
HIPERLAN	High performance Local area network
IEEE	institute of electrical and electronics engineering
IMT	International mobile telecommunication
ISM	internation standard for mobile communication
MHz	Mega Hertz
MMIC	Microwave and millimeter wave integrated circuits
MoM	Method of moments
MSA	microstrip patch antenna
PDA	personal digital assistant
PEC	Perfect electric conductor
RFID	Radio frequency Identification
UMTS	Universal Mobile for Telecommunication
UWB	Ultra Wideband Antenna
VSWR	voltage standing wave ratio
WiFi	Wireless Fidelity
WiMAX	Worldwide interoperability for Microwave access
WLAN	wireless local area network
WPAN	Wireless personal area network

Chapter 1
INTRODUCTION

This chapter gives a brief introduction about different wireless standards and importance of a microstrip patch antenna. After defining the objective of the thesis, chapter 1 closes with an outline of the thesis, listing a brief summary of the topics discussed in each chapter of the thesis.

1.1 Introduction

Presently wireless communication, by measure is the fastest growing segment of the communication field. There are many government and commercial applications such as mobile radio, Satellite communication and Wireless communication where weight, size, cost, performance, ease of installation, aerodynamics profile are major constraints. The vision of the wireless communication supporting information exchange between people and devices is the communication frontier of the next few decades. This vision will allow multimedia communication from anywhere in the world. In the last few years, the development of wireless local area networks (WLAN) and WIMAX (Worldwide Interoperability for Microwave Access) represented one of the principal interests in the information and communication field. Also, in today's environment, technology demands antennas which can operate on different wireless bands and should have different features like low cost, minimal weight, low profile and are capable of maintaining high performance over a large spectrum of frequencies.

In this era of next generation networks we require high data rate and size of devices are getting smaller day by day. In this evolution two important standards are Wi-Fi (WLAN) and Wi-MAX. Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (Wi-MAX) technology is most rapidly growing area in the modern wireless communication. This gives users the mobility to move around within a broad coverage area and still be connected to the network. This provides greatly increased freedom and flexibility. For the home user, wireless has become popular due to ease of installation, and location freedom. For success of all these wireless applications we need efficient and small antenna as the size of the device is becoming smaller and smaller. This being the case, portable antenna technology has grown along with mobile and cellular technologies. It is important to have the best performance antenna for a device. The best performance antenna will improve transmission and reception, reduce power consumption, last longer and improve marketability of the communication device.

This technological trend has focused much effort into the design of Microstrip patch antennas. With a simple geometry, patch antennas exhibits many advantages on other conventional antennas [1]:

- ❖ Capable of providing both linear and circular polarization.
- ❖ Inexpensive to fabricate using modern day printed circuit board technology,
- ❖ Compatible with microwave and millimeter-wave integrated circuits (MMIC),
- ❖ Ability to conform to planar and non planar surfaces.

Microstrip antennas (MSA) have some good features written above. Due to these advantages, Microstrip antennas (MSA) are well suited for WLAN/WiMAX application systems. Microstrip antennas (MSA) have some disadvantages also like narrow bandwidth, low gain etc.

Next Generation devices have also more than one application embedded in single device so antenna supporting more than one band is required and multiband operation of antenna is another challenge. Dual-band wireless phones have become popular recently because they allow using the one phone in two networks that have different frequencies. Tri-band phones have also gained popularity. Still, there exist more than three frequency bands used for wireless applications. Table 1-1 lists a few useful wireless applications and their operating frequencies. The systems having multi-band operation require antennas that resonate at the specified frequencies.

Microstrip antennas (MSA) have characteristics like low cost and low profile which proves microstrip antennas to be well suited for WLAN/Wi-MAX application systems. MSA have some limitations like narrow bandwidth, low gain etc. However these problems can be solved by special techniques which make antennas to work efficiently for wider range of frequencies, i.e. Wider Bandwidth. Microstrip patch, with inserted slits at one of the radiating edges, is one of the techniques of widening the bandwidth of the antenna.

1.2 WLAN (wireless local area network) and its standards

A wireless local area network (WLAN) links two or more devices using some wireless distribution method and usually providing a connection through an access point to the wider internet. The IEEE standards for wireless local area network were developed by IEEE and include four subsets of Ethernet based protocol standards [4]:

- 802.11
- 802.11a
- 802.11b
- 802.11g
- 802.11n

In 1997, the Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN standard. They called it 802.11 after the name of the group formed to oversee its development. Unfortunately, 802.11 only supported a maximum network bandwidth of 2 Mbps - too slow for most applications.

802.11a operates in the 5 - 6 GHz range with data rates commonly in the 6 Mbps, 12 Mbps, or 24 Mbps range. Because 802.11a uses the orthogonal frequency division multiplexing (OFDM) standard, data transfer rates can be as high as 54 Mbps.

The 802.11b standard (also known as Wi-Fi) operates in the 2.4 GHz range with up to 11 Mbps data rates and is backward compatible the 802.11 standard. 802.11b uses technology known as complementary code keying (CCK) modulation, which allows higher data rates.

In 2002 and 2003, WLAN products supporting a newer standard called 802.11g emerged on the market. 802.11g attempts to combine the best of both 802.11a and 802.11b. 802.11g supports bandwidth up to 54 Mbps, and it uses the 2.4 GHz frequency for greater range.

The newest IEEE standard in the Wi-Fi category is 802.11n. It is designed to improve on

802.11g in the amount of bandwidth supported by utilizing multiple wireless signals and antennas (called MIMO technology) instead of one.

1.3 WiMAX (Worldwide Interoperability for Microwave Access) and its standards

WiMAX (Worldwide Interoperability for Microwave Access) is the next-generation of wireless technology designed to enable pervasive, high-speed mobile Internet access to the widest array of devices including notebook PCs, handsets, smart phones, and consumer electronics such as gaming devices, cameras, camcorders, music players, and more. WiMAX is a telecommunications protocol that provides fixed and mobile Internet access. The name WiMAX was created by the WiMAX forum which was formed in June 2001 to promote conformity and interoperability of the standard. The current WiMAX revision provides up to 40 Mbit/s with the IEEE 802.16m update expected to offer up to 1 Gbit/s fixed speeds. The IEEE 802.16 standard forms the basis of 'WiMAX' and is sometimes referred to colloquially as "WiMAX", "Fixed WiMAX", "Mobile WiMAX", "802.16d" and "802.16e" Clarification of the formal names are as follow [5]:

- 802.16-2004 is also known as 802.16d, which refers to the working party that has developed that standard. It is sometimes referred to as "Fixed WiMAX," since it has no support for mobility.
- 802.16e-2005, often abbreviated to 802.16e, is an amendment to 802.16-2004. It introduced support for mobility, among other things and is therefore also known as "Mobile WiMAX".

Different standards referred by IEEE are given in Table 1.1 shown below, table describes the different wireless bands and corresponding bandwidth suggested for different standards. It can be analyzed from the table that every standard operates at different frequency, so requires different antenna resonance for different standard. Due to high requirement of data rate bandwidth requirement is also high.

Table 1.1 Various types of wireless applications and its frequency band

Wireless Applications		Frequency Band (MHz)	Bandwidth (MHz)
GSM	GSM 900	890-960	70
	GSM 1800	1710-1805	95
	GSM 1900	1850-1990	140
IMT		2300-2400	100
		2700-2900	200
		3400-4200	800
		4400-4900	500
WLAN		2400-2484	84
		5150-5350	200
		5725-5825	100
Bluetooth		2400-2500	100
Wi-MAX		2500-2690	190
		3400-3690	290
		5250-5850	600

1.4 Applications

The advantages of microstrip antennas far outweigh their disadvantages. Hence there are many different successful applications. With continuing research and development and increased usage of microstrip antennas it is expected that they will ultimately replace conventional antennas for many applications. Some important applications for which microstrip antennas have been developed are:

- Satellite communication, direct broadcast services
- Radio altimeter
- Command and control
- Remote sensing
- Satellite navigation receiver
- Weapon fuzing
- Missile and telemetry

1.5 Objective of the Thesis

1. Study of different shaped Microstrip Antennas for WLAN applications.
2. (a) Design and simulation of Coaxial fed dual band microstrip patch antenna for WLAN applications using rectangular patch.

   (b) Design and simulation of Coaxial fed dual band microstrip patch antenna for WLAN applications using triangular patch.

   (c) Design and simulation of Coaxial fed dual band microstrip patch antenna for WLAN applications using pentagon patch.
3. Parametric studies and fabrication of the simulated antennas.

1.6 Outline of the Thesis

In chapter 1 Microstrip Patch Antenna design with advantage of using these kinds of antennas has been presented. An overview of Wireless standards is presented next. It is concluded that Microstrip patch antenna resonates at particular frequency so the frequency of operation of each standard is important.

In chapter 2 various feeding techniques with transmission line model for analysis of microstrip patch antenna is discussed. This chapter also includes different challenges in design of Microstrip Patch antenna. It is inferred that though lots of work has already been done in this field, but as wireless standards evolving day by day thereby introducing challenges in design of microstrip patch antenna.

In chapter 3 literature survey is presented explaining the work that is already been published by the authors in context of Microstrip patch antenna design.

In chapter 4 simulation results of dual band Microstrip patch antennas having different shapes of patch are presented. Different shapes include triangular, rectangular and pentagon shaped antennas. From discussion of results it is concluded that these antennas operate on dual band and resonate at 2.4GHz and 5.2GHz . The simulated results for return loss, radiation pattern and smith chart are also shown. The effects of various parameters like feed point location, patch length and position of the slot are also shown graphically. It is also concluded that pentagonal patch antenna provides better performance than that of rectangular and triangular patch antenna considering the return loss and bandwidth simultaneously.

Chapter 5 shows the fabrication steps used to fabricate the simulated antennas in PCB FABRICATION LAB. The instruments used to fabricate the antennas are also shown.

Chapter 2

OVERVIEW OF MICROSTRIP PATCH ANTENNA AND FEEDING TECHNIQUES

2.1 Overview

In high-performance aircraft, spacecraft, satellite and missile applications, we have small size, less weight, low cost, high performance, ease of installation, and aerodynamic profiles are constraints, so we require low profile antennas. Presently there are many other government and commercial applications, such as mobile radio and wireless communications that have similar specifications. To meet these requirements, Microstrip antennas can be used. These antennas are low profile, conformable to planar and non planar surface, simple and inexpensive to manufacture using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, and when the particular patch shape and mode are selected; they are very versatile in terms of resonant frequency, polarization, pattern and impedance. In addition by adding the load between patch and ground plane such as pins, adaptive elements with variable resonant frequency, impedance, polarization and pattern can be designed.[1]

The concept of Microstrip radiators was first proposed by Deschamps in 1953. A patent was issued in France in 1955 in the names of Gutton and Baissinor. However 20 years passed before practical antennas were fabricated. Development during the 1970’s was accelerated by the availability of good substrates with low loss tangent and attractive thermal and mechanical properties, improved photolithographic techniques, and the better theoretical models. The first practical antenna was developed by Howell and Munson.

A microstrip patch antenna consists of the following:

- A radiating patch (perfect electric conductor)
- Substrate
- Ground (perfect electric conductor)

An example of Microstrip patch antenna with rectangular shaped patch and feed from Coaxial feed is shown in fig.-2.1 below. Important parameters in designing Microstrip patch antennas are:

- Shape of Metallic Patch
- Substrate Thickness
- Substrate dielectric constant and tangent loss
- Type of feed used.

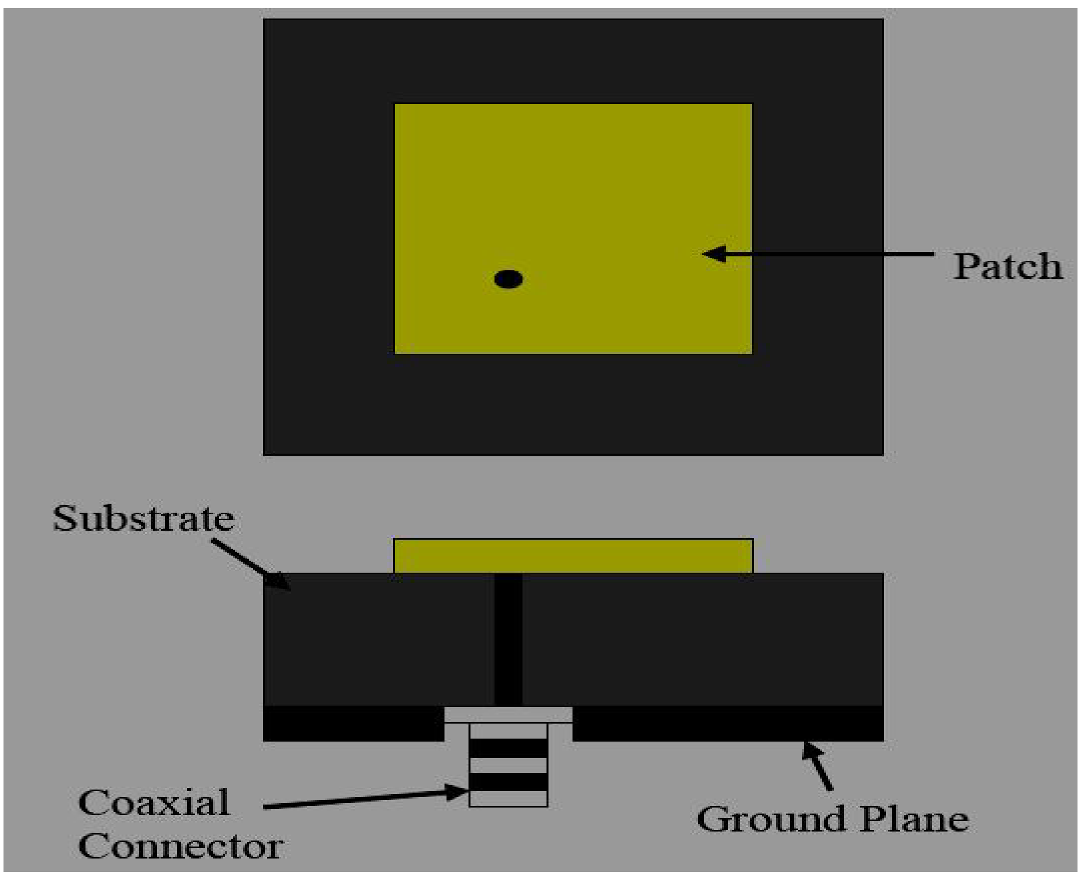


Fig 2.1: Structure of Microstrip Patch antenna with rectangular shaped patch

The patch can be designed of desired shape as shown in figure 2.2 but square, rectangular and circular shapes are the most common because of the ease of analysis and fabrication. [1]

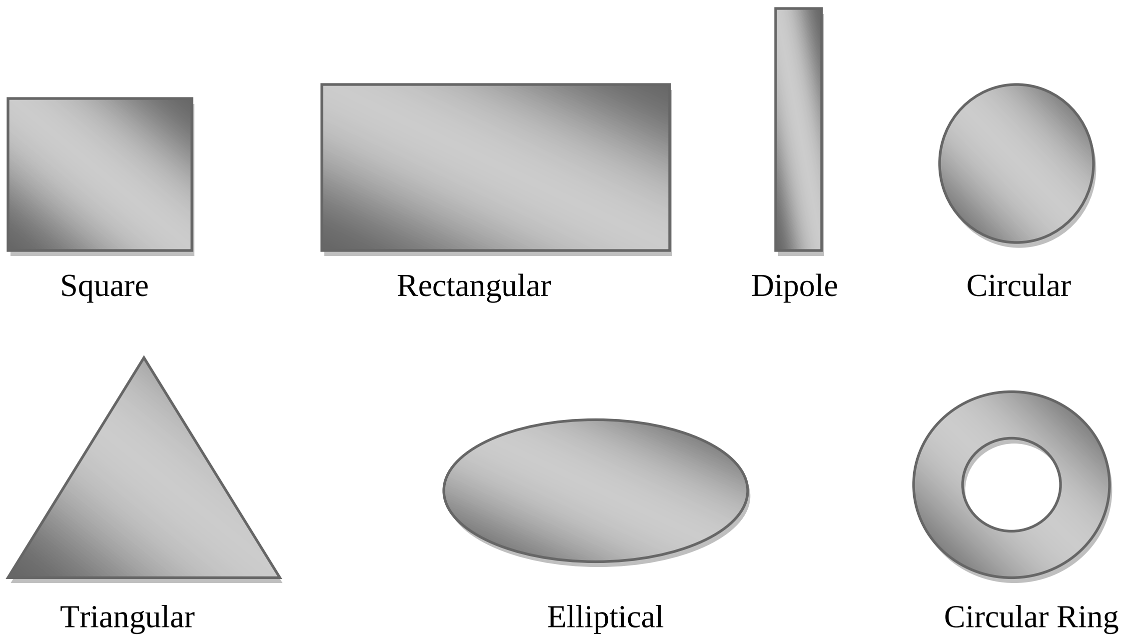


Fig 2.2: Common shapes of patches for Microstrip Patch antenna

2.2 Importance of Microstrip Patch Antennas

Microstrip Antennas have several advantages compared to conventional microwave antenna and therefore many applications cover the broad frequency range from 100 MHz to 100 GHz. Some of the principal advantages of Microstrip antennas compared to conventional Microwave antennas are: [1]

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence can be manufactured in large quantities.
- Linear as well as circular polarizations are possible with simple feed.
- Can be easily integrated with microwave integrated circuits (MICs).
- Capable of multiple frequency operations.
- Mechanically robust when mounted on rigid surfaces.
- Easy to manufacture because fabrication can be done in PCB lab.

However, Microstrip Antennas also have some limitations compared to conventional microwave antennas which are given below:

- Narrow bandwidth and associated tolerance problems.
- Low efficiency.
- Somewhat lower Gain (6 dB).
- Large ohmic loss in the feed structure of arrays.
- Extraneous radiation from feeds and junctions.
- Poor end fire radiator except tapered slot antennas.
- Low power handling capacity.
- Surface wave excitation.

2.3 Feeding techniques

One of the important aspects of microstrip patch antenna is the variety of feeding technique applicable to them. Microstrip patch antennas have radiating elements on one side of a dielectric substrate and thus may be fed by a variety of methods. Matching is usually required between the feed line and the antenna input impedances. A good impedance matching condition between the line the patch without an additional matching elements depends heavily on feeding technique used. These techniques can be classified into two categories-

- Contacting and
- Non-contacting

In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The feeding techniques used for the excitation of microstrip patch antenna are:

- The microstrip line feed (contacting schemes) [1]
- Coaxial probe (contacting schemes) [2]
- Aperture coupling (non-contacting schemes) [3]
- Coplanar waveguide feed (contacting schemes) [3]
- Proximity coupling (non-contacting schemes) [3]

2.3.1 Microstrip line feed

In this technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in Figure 2.3. The conducting strip is smaller in width as compared to the patch and microstrip line patches have several advantages over other feeding technique. Since the feed layout and patches can be on one board, it eases fabrication. The level of input impedance is easily controllable. The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. The corresponding equivalent diagram is shown in figure 2.4 which consists of two inductors, one resistance and one capacitor.

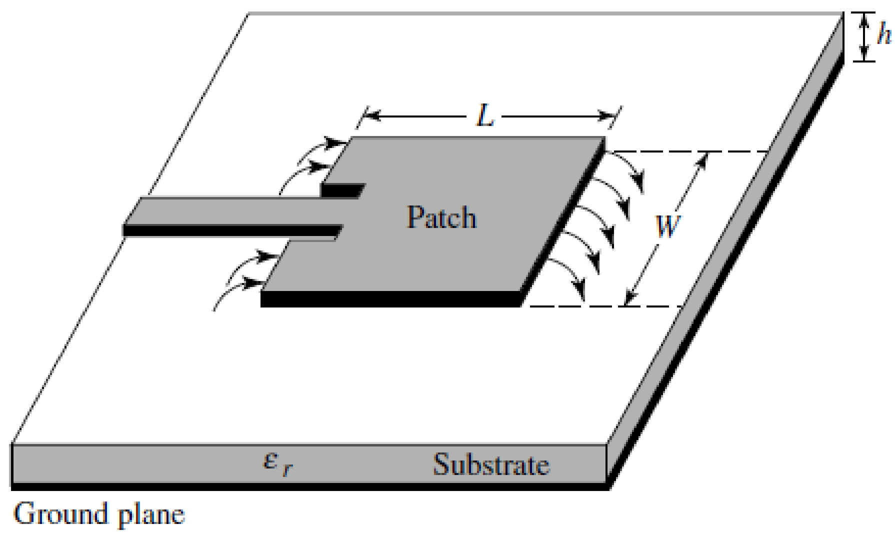


Figure 2.3 Microstrip line feed with inset cut [1]

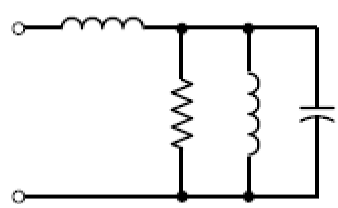
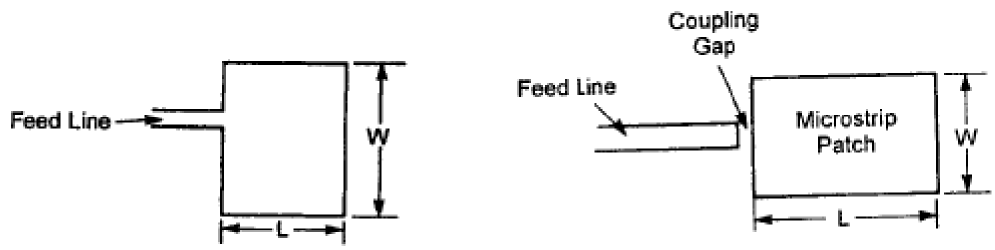


Figure 2.4 Equivalent circuit for Microstrip line feed [1]



(a) **(b)**

Figure 2.5 Microstrip line feed (a) at the radiating edge (b) with coupling gap

The coupling between the patch and microstrip line could be in the form of inset cut shown in figure 2.3 or edge/butt-in coupling as shown in figure 2.5(a) or through a gap between them as shown in figure 2.5(b).

However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. The feed radiation also leads to undesired cross polarized radiation.

2.3.2 Coaxial feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from figure 2.6, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. Its equivalent circuit is shown in figure 2.7. The coaxial feed, using Huygens's principal, can be modeled by a cylindrical band of electric current flowing on the center conductor from the bottom to top along with the annular ribbon of magnetic current in the ground plane. An idealization that simplifies the computation is to replace the electric current by a uniform line current ribbon. To determine the probe impedance for a microstrip antenna, the canonical problem of a parallel plate waveguide fed by a coaxial line has been analyzed using the integral formulation. The geometry for calculating the impedance is shown in fig.2.8

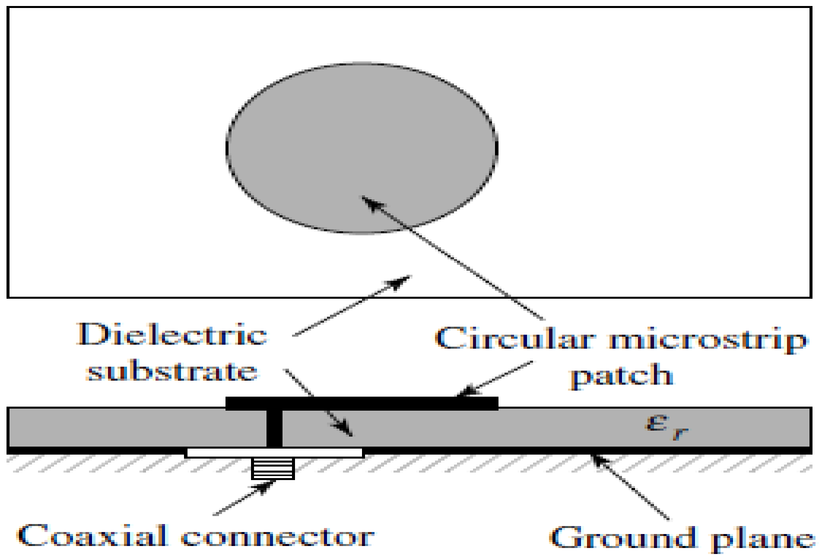


Figure 2.6 Probe fed rectangular microstrip patch antenna [1]

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation

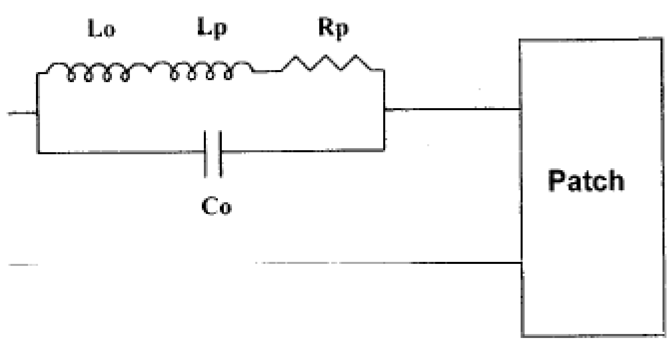


Figure 2.7 Equivalent circuit for coaxial feed or Probe feed [2]

However, its major drawback is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda_o$).

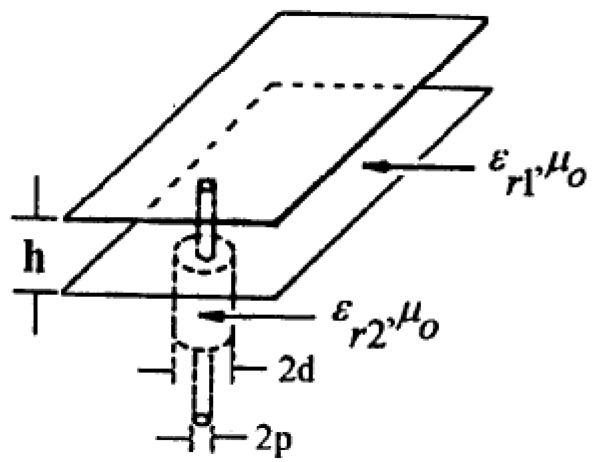


Figure 2.8 Geometry for coaxial feed or Probe feed [2]

Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these problems.

2.3.3 Aperture coupled feed

In this type of feeding technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 2.9. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane. The coupling aperture is usually centered under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture.

A more cleared sketch of aperture coupled microstrip patch is shown in figure 2.10. The feed line is along the resonant dimension of the patch. The slot, therefore, has its length perpendicular to the resonant dimension.

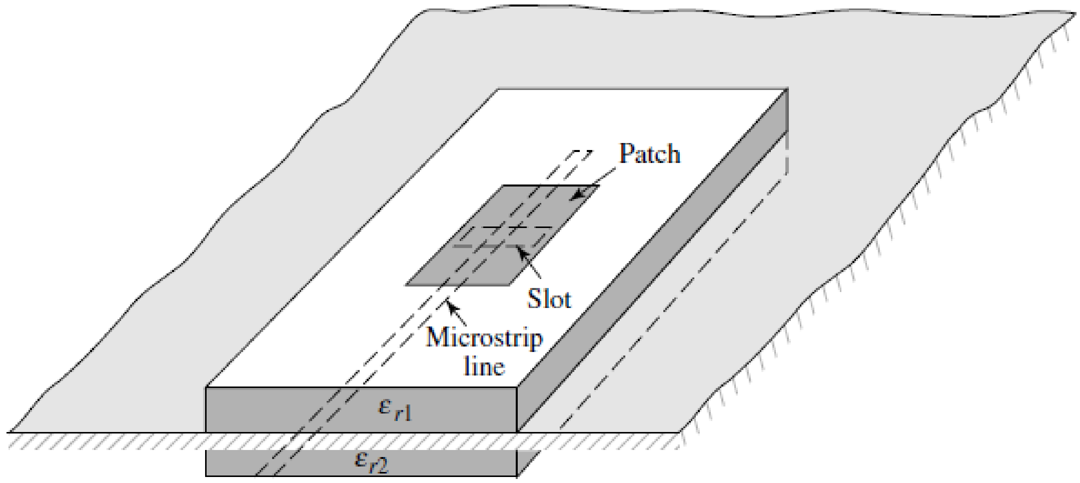


Figure 2.9 Aperture-coupled feed [1]

The slot, therefore, has its length perpendicular to the resonant dimension. The feed line is narrower than the slot. In aperture coupling, the patch is in series with the feed line. The aperture is too small to be resonant, so it contributes only a reactance to the impedance. The stub beyond the slot also presents a series reactance. An equivalent circuit for the antenna is shown in figure 2.11. L` represents the inductance associated with the below resonance slot. The patch is a parallel RLC circuit. The stub is an open circuited transmission line with the same characteristic impedance as the feed line. The stub compensates for the inductance of the slot and the patch to help to create real input impedance for the antenna.

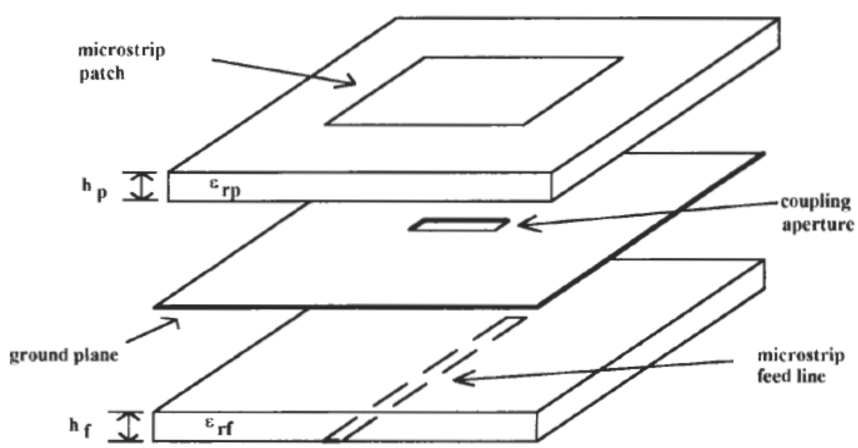


Fig.2.10 Aperture-coupled microstrip patch [3]

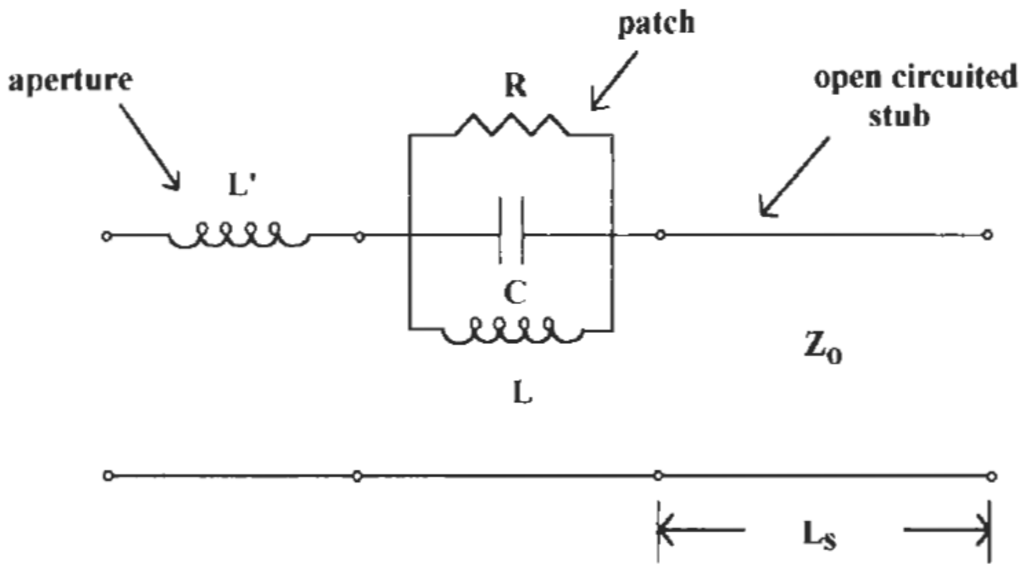


Figure 2.11 Equivalent circuit for Aperture-coupled feed [3]

Since the ground plane separates the patch and the feed line, spurious radiation is minimized. The location of the slot in ground plane can be varied to get the maximum coupling between patch and the feed line. The aperture coupling scheme provides the maximum bandwidth i.e. 21%. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness.

2.3.4 Proximity coupled feed

This type of feeding technique comes under non contacting scheme as there is no physical contact between patch and feed line. This scheme is also called as the electromagnetic coupling scheme. As shown in Figure 2.12, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances. The line impedance can be controlled by varying the length and width of the feed line.

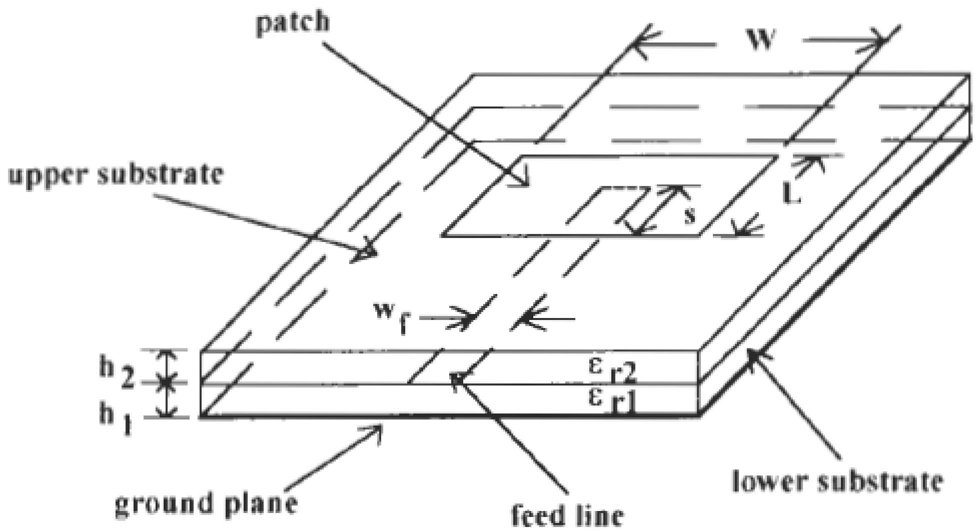


Figure 2.12: Proximity-coupled feed [3]

The patch is considered to be electromagnetically coupled (EMC) to the feed and is often called an EMC patch. The coupling mechanism is predominantly capacitive. An approximate equivalent circuit at a point on the feed line right at the patch edge is given in figure 2.13. The parallel RLC circuit represents the patch itself. C_C is the coupling from the feed to the patch. The coupling is controlled by two factors, the inset distance of the feed and the patch width. The coupling increases with feed inset reaching a maximum when s=L/2. The coupling is symmetrical with respect to the center of the patch. Decreasing the patch width increases the coupling.

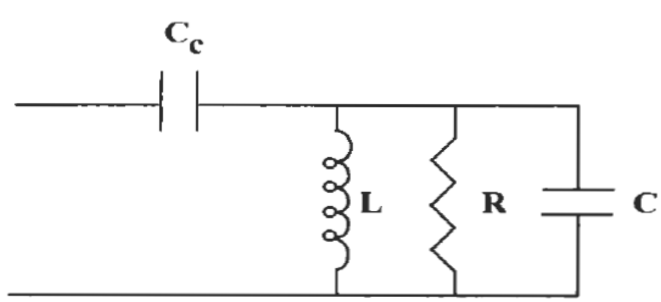


Figure 2.13: Equivalent circuit for Proximity-coupled feed [3]

Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate Microstrip Line Patch because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

2.3.5 Coplanar Waveguide Feeding

Coplanar waveguide is a transmission line system consisting of a central current-carrying trace on the top of a substrate, coplanar with side grounds extending beyond a symmetric gap to either side of trace. A coplanar waveguide (CPW) is the preferred transmission line for microwave monolithic integrated circuits (MMIC). Both CPW and microstrip antennas belong to the planar geometry. Therefore, for integrating microstrip antennas with CPW, it is desirable to feed the microstrip antenna with a CPW. The coplanar waveguide (CPW) fed antenna have been widely used for wireless communications owing to their many attractive features such as wide bandwidth, simplest structure of a single metallic layer, no soldering points, easy integration with MMICs etc.

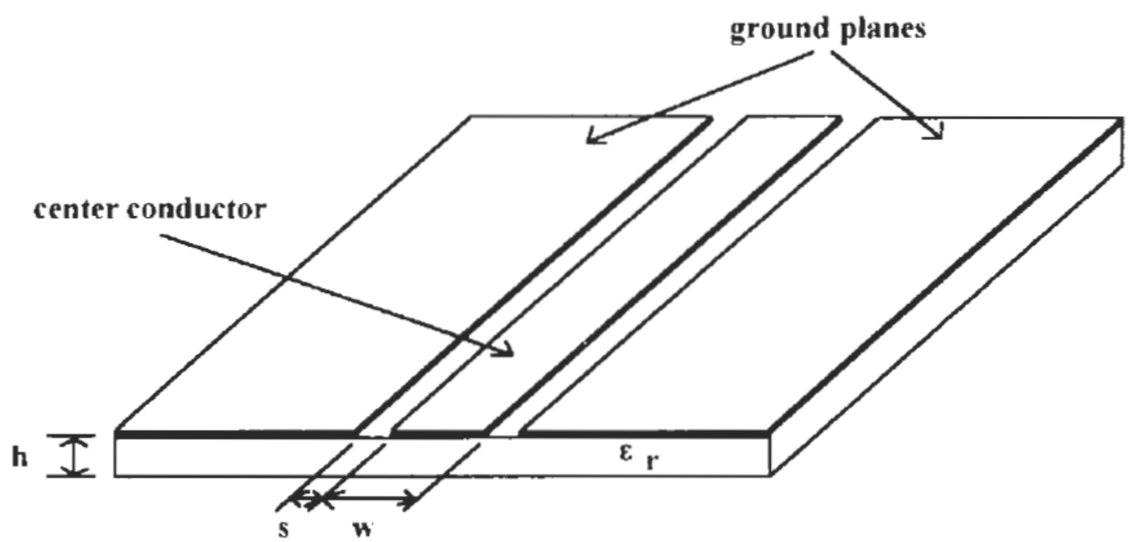


Figure 2.14: Coplanar Waveguide feed [3]

Here, the CPW is etched in the ground plane of the microstrip antenna. Coupling is accomplished via a slot. Three possibilities with this excitation are shown. In figure 2.15(a) the center conductor of the CPW divides the coupling slot into two. The CPW is transformed into a slot of length L_s in figure 2.15(b). The coupling between CPW and patch is inductive in figure 2.15(a) while is capacitive in figure 2.15(b).

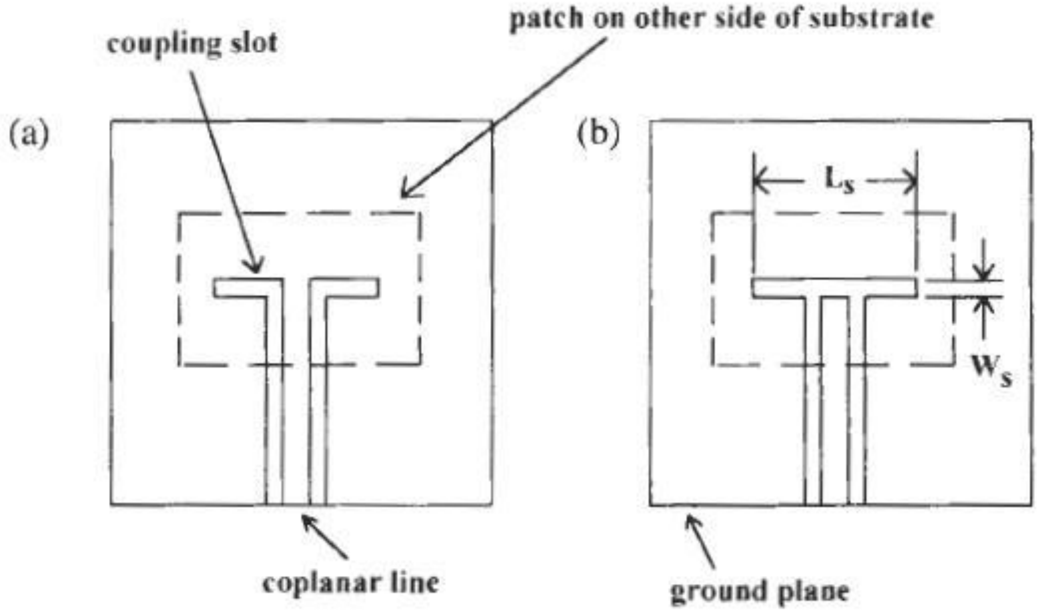


Figure 2.15: Coplanar Waveguide fed antennas: (a) inductive coupling (b) capacitive coupling [3]

2.4 Analytical Models of Analysis

There are various methods of analysis for microstrip antennas. The most popular models are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate and it is more difficult to model coupling. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature. The mainly three models are explained below:

- Transmission line model
- Cavity model

❖ Full wave model

Transmission line model:

The transmission line model is the easiest of all but it yield the least accurate result and it lacks the versatility. However it does shed some physical insight. Basically the transmission line model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially nonhomogeneous line of two dielectrics, typically the substrate and air.

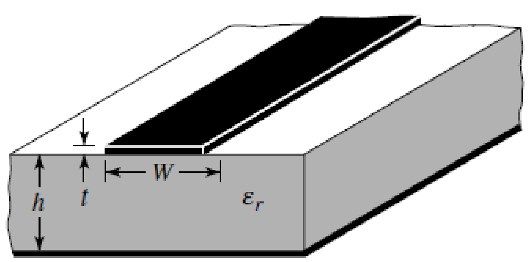


Figure 2.16 Microstrip line [1]

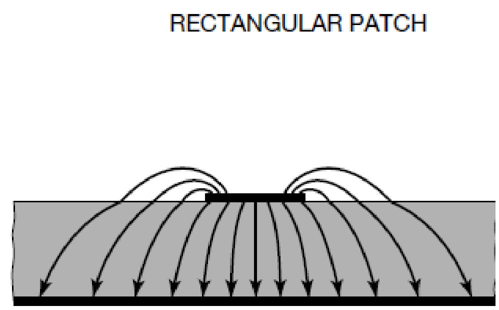


Figure 2.17 Electric field lines [1]

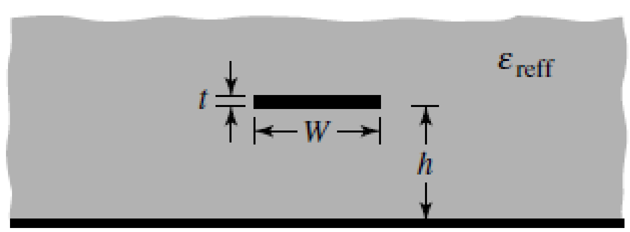


Figure:-2.18 Effective dielectric constant [1]

Fringing effect:

Because of dimension of the patch are finite along the length and width, the fields along the edges of the patch undergo fringing. This is shown in figure 2.21. Hence, as seen from Figure 2.21, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electromagnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi- TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line as shown in figure 2.22. The value of ε_{reff} is slightly less than ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in figure 2.21 above. The expression for ε_r is given in as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}} \tag{3.1}$$

Where = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

w = Width of the patch

2.5 CHALLENGES IN DESIGN OF MICROSTRIP PATCH ANTENNA

In a simple way we can say that "an antenna is the transitional radio b/w free space and a guiding device." while designing a Microstrip Antenna there are some parameters that should be taken very carefully. These challenges are:

2.5.1 Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio of the maximum to minimum voltage transmitted by antenna.It can be written as:

$$VSWR = V_{max} / V_{min}$$

$$= (V_i + V_r)/(V_i - V_r) \tag{3.2}$$

where V_i is the incident voltage

V_r is the reflected voltage

2.5.2 Reflection Coefficient |Γ| and Characteristic Impedance (Z_0)

There is a reflection that occurs in the transmission line when we take the higher frequencies in to consideration. There is a resistance that is associated with each transmission line which comes with the construction of the transmission line. This is called as character impedance (Z_0). The standard value of this impedance is 50 **Ω**. Always the every transmission line is being terminated with an arbitrary load Z_L and this is not equivalent to the impedance i.e. Z_0. Here occurs the reflected wave.

The degree of impedance mismatch is represented by the reflection coefficient at that load and is given by:

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_{L-}Z_0}{Z_L+Z_0} \tag{3.3}$$

We can observe here that the reflection coefficient for the shorted load Z_L=0, there is a match in the load Z_L=Z_0 and an open load Z_L= ∞ are -1, 0, +1 . Hence we can say that the reflection coefficient ranges from 0 to +1. For a microstrip antenna VSWR should be less than 2.

2.5.3 Return loss of -15 dB or less

Return Loss is the best and convenient method to calculate the input and output of the signal sources. It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the 'Return loss'.

This Return Loss is determined in dB as follows:

$$R_L = -20log|\Gamma| \ (dB) \tag{3.4}$$

$$here \ |\Gamma| \ is \ \frac{V_0^-}{V_0^+} = \frac{Z_{L-}Z_0}{Z_L + Z_0}$$

|Γ| = is the reflection coefficient

V_0^- = is the reflected voltage

V_0^+ = is the incident voltage

Z_L and Z_0 are the load and characteristic impedence.

During the process of the design of the rectangular patch antenna there is a response taken from the magnitude of S_{11} versus the frequency (this is known as the return loss), as shown in the figure, just as the verification of the design.
The figure 2.19, it shows that the microstrip patch antenna is resonating at 5.2 GHz having a return loss of -33.652dB and -10dB bandwidth is 376.8 GHz.

To have a perfect matching between the antenna and the transmitter, Γ=0 and $R_L = \infty$, this indicates that there is no power that is returned or reflected but when Γ=1 and R_L = 0 dB, this indicate that the power that is sent is all reflected back. For the practical applications VSWR=2 is acceptable as the return loss would be -9.54 dB or -10dB.

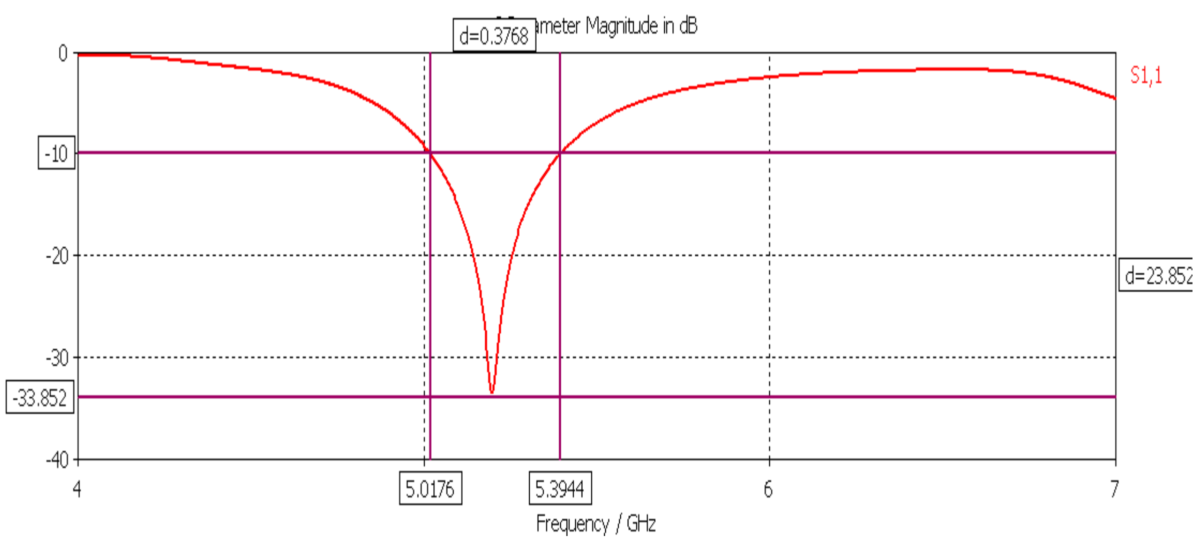


Figure 2.19: S_{11} (return loss) for 5.2 GHz rectangular patch antenna

During the process of the design of the rectangular patch antenna there is a response taken from the magnitude of S_{11} Vs the frequency (this is known as the return loss).

2.5.4 Bandwidth

Bandwidth can be said as the frequencies on both the sides of the centre frequency in which the characteristics of antenna such as the input impedance, polarization, beam width, radiation pattern etc. are almost close to that of this value. As the definition goes "the range of suitable frequencies within which the performance of the antenna, w.r.t some characteristic, conforms to a specific standard".

The bandwidth is the ratio of the upper and lower frequencies of an operation, expressed as

$$BW_{broadband}(\%) = \frac{f_H}{f_L} \quad (3.5a)$$

$$BW_{narrowdband}(\%) = \left[\frac{f_H - f_L}{f_C}\right] 100 \quad (3.5b)$$

When the ratio of $f_H/f_L = 2$, the antenna is said to be broadband. We can judge the antenna's performance by operating the antenna at high frequency by observing VSWR, when VSWR ≤ 2 (RL≤ -9.5 dB) the antenna is said to have performed well.

2.5.5 Radiation Pattern

Microstrip Patch Antenna has radiation patterns that can be calculated easily. The source of the radiation of the electric field at the gap of the edge of the Microstrip element and the ground plane is the key factor to the accurate calculation of the pattern for the patch antenna.

Simply it can be said that the power radiated or received by the antenna is the function of angular position and radial distribution from the antenna. The radiation pattern of a generic dimensional antenna can be seen below, which consist of side lobe, black lobes, and are undesirable as they represent the energy that is wasted for transmitting antennas and noise sources at the receiving end.

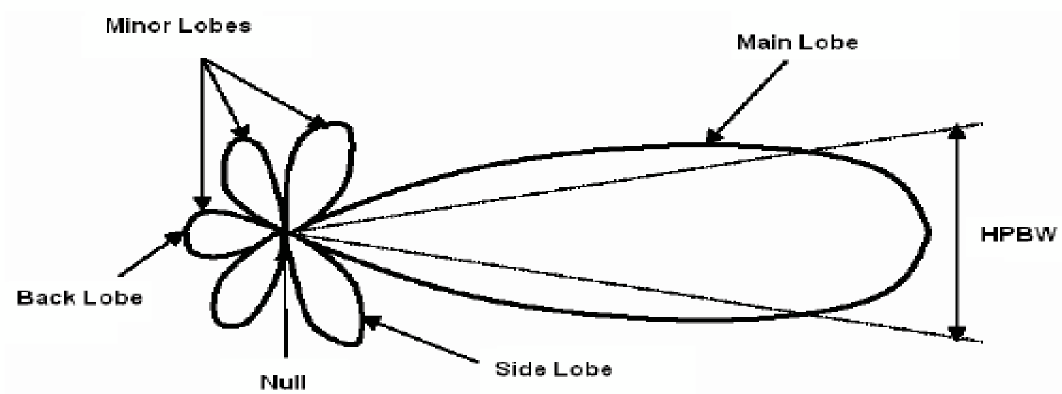


Fig: 2.20: Radiation Pattern of a generic dimensional antenna

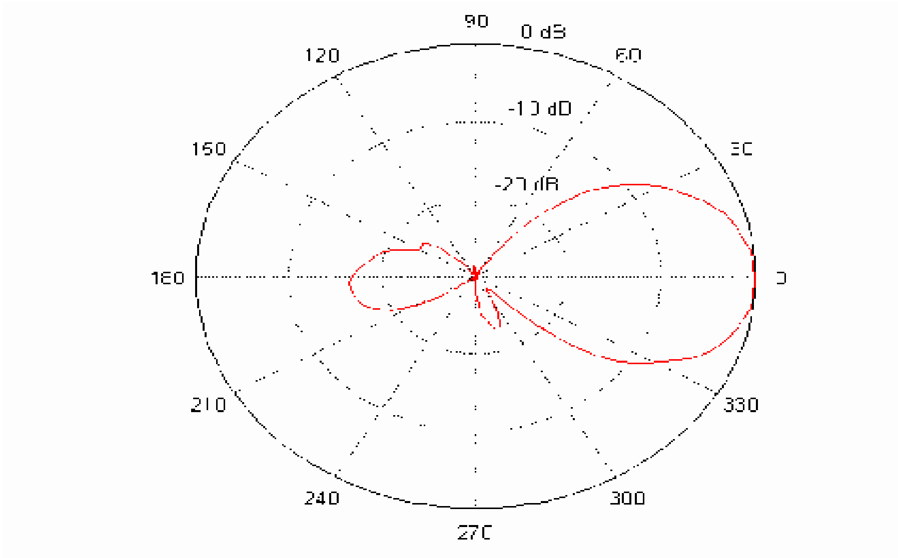


Fig. 2.21: A general radiation pattern for a Microstrip antenna

2.5.6 Matched feed point

The designed antenna performs best when the transmission line is placed at a point where the current does not face any obstruction, and can be easily distributed over the entire patch. The feed point is selected in such a way so that there will be a minimum return loss.

Chapter 3

LITERATURE SURVEY

Prior to stating of my thesis, it is important to have a deep understanding on the existing pages of Microstrip antenna. The main sources of information for the dissertation are books, journal, theses and dissertations and the internet. There are three major areas of reading in the literature review, which are antenna design, methods for improving performance of Microstrip patch antenna and related simulation software. These chapters include the research paper literature review.

Dual Band Microstrip Antenna for Wireless LAN Application [6]

This paper discusses the design of the multiband Microstrip antenna operating at frequency 2.4 GHz and 5.2GHz. The aim was to design a dual band Microstrip antenna which will be operating in the wireless LAN band, IEEE 802.11 a/b/g. The dimensions of the single elements of the operating frequencies were calculated using transmission line model. Two elements of inset fed Microstrip antenna were used for each frequency band. In this paper, there are four elements to cover the frequency band for WLAN application. The simulation process was done using the Agilent ADS software. The scaling factor of 1.03 has been chosen for the design starting from the lowest resonating frequency at 2.4 GHz band, while at 5.2 GHz band, the scaling factor is 1.05. The difference on the scaling factors was contributed by the losses that occurred when combining both of the antenna elements from both bands of frequency. The antenna has been fabricated on the FR4 microstrip board with ε= 4.5 and tan δ 0.019 using the wet etching technique.

A Novel Frequency/Pattern-reconfigurable Microstrip Antenna for WLAN Applications [7]

The design of a frequency and pattern reconfigurable monopole-type printed antenna is presented in this paper. The antenna features a circular patch fed using a microstrip line, a shape-optimized partial ground plane, and two PIN diodes mounted over two slots in the ground plane. Three switching cases are considered. The first results in a single-band operation at 5.2 GHz, whereas the other two cases offer a dual-band operation, at 2.4 GHz and 5.2 GHz. In all three cases, an omni directional radiation pattern is obtained in the 5.2 GHz band. However, in the two cases where operation at 2.4 GHz is possible, an equal gain E-plane pattern and 180° switchable H-plane patterns are offered depending on the switching condition.

Design of Microstrip Antenna for Bluetooth and WAN Applications by Applying Modified Smith chart Representation [8]

Calculation methods for for Microstrip line parameters by hank calculator and/or by personal computer are needed for preliminary design purposes, and/or for quick evaluation purposes. In this research, the proposed algorithm depicting the dynamic permittivity of the Microstrip structure directly leads to a convenient and modified Smith chart representation that includes the frequency-dependent influence of fringing field and the lossy characteristics cohesively. Results based on the proposed model are compared with the available data in the literature in respect to a Microstrip patch antenna in the frequency range of Wireless Personal Area Network (WPAN) applications such as Bluetooth and Wireless Local Area Network (WLAN). This model is compatible for CAD efforts with MATLAB facilitating fast and user-friendly implementations.

A Novel dual-band Microstrip antenna for WLAN applications [9]

A novel compact Microstrip fed dual-band Microstrip antenna for wireless local area network is presented. The antenna generates two separate resonant modes to cover 2.4/5.2 GHz WLAN bands. The lower resonant mode of the antenna has an impedance bandwidth (S11< -lOdB) of 220 MHz (2340-2560 MHz), which easily covers the required bandwidth of the 2.4 GHz WLAN, and the upper resonant mode has a bandwidth of 380MHz (5040- 5420MHz), covering 5.2 GHz WLAN band. The proposed antenna will have smaller size (16mm X 16mm, ε_r = 2.45) due to no ground plane extension.

M-shaped dielectric resonator antenna for WLAN applications [10]

In this paper, a new dielectric resonator antenna (DRA) is designed for WLAN applications, where a simple M-shaped dielectric resonator (DR) is excited by a conformal patch connected to a microstrip line. The simulation process was done by using computer simulation Technology (CST) Microwave studio suite 2010.The simulated results show that the proposed DRA achieves an impedance bandwidth of about 31.32% for VSWR ≤ 2, covering a frequency range from 4.63 GHz to 6.35 GHz. The antenna also provides a gain range of 5.64-7.34 dB across the operating bandwidth. The proposed antenna is suitable for wireless local area networks (WLAN 5.15-5.30GHz) (IEEE 802.11a). It has also application in high performance radio LAN (HIPERLAN) which operates across 5.15 to 5.30 GHz.

A Compact wide band patch antenna for WLAN application [11]

In this paper, a design and analysis of compact probe fed slot antenna is presented. The proposed antenna has simple structure consisting Ω-shape on a rectangular patch, the overall dimension of the antenna come around 36mm*26mm*5.127mm and fed by 50Ω probe feed. The impedance matching and radiation characteristics of the designed structure are investigated by using MOM based IE3D. The simulation results show that the antenna impedance bandwidth of the antenna reaches about 31 %(4.25GHz-5.8GHz) with return loss better than -10 dB over the chosen frequency spectrum. The proposed antenna gain of 9dBi and 7dBi are achieved. Its radiation patterns are also studied.

Inverted U-Shaped Dielectric Resonator Antenna for WLAN [12]

A Dielectric resonator antenna design is presented for Wireless Local Area Network (WLAN) applications. By using a dielectric resonator with an inverted U-shape cross section and optimized rectangular patch adhered in between the dielectric resonator as a feeding mechanism, an impedance bandwidth of about 15.7% and covering a frequency range of 5.1 to 5.97 GHz is achieved and resonating at 5.5GHz. The proposed antenna is suitable for wireless local area networks (WLAN) applications in 5-6 GHz frequency range. This U Shaped DRA exceeds the bandwidth requirements for the IEEE 802.11a wireless local area network (WLAN) applications (5.15-5.35 GHz and 5.725-5.825 GHz) within a 2:1 VSWR.

Polarization Reconfigurable U-Slot Patch Antenna [13]

A compact U-slot Microstrip patch antenna with reconfigurable polarization is proposed for wireless local area network (WLAN) applications. PIN diodes are appropriately positioned to change the length of the U-slot arms, which alters the antenna's polarization state. Two antenna prototypes with identical dimensions are designed, fabricated and measured. The first antenna prototype enables switching between linear and circular polarization by using a PIN diode and a capacitor located on the U-slot. The second antenna prototype uses two PIN diodes to switch between the two circular polarization senses. A good impedance match (S11 <- 10 dB) for both linear and circular polarization is achieved from 5.725 to 5.85 GHz, a band typically used for WLAN applications, and the 3 dB axial ratio bandwidth is greater than 2.8%. Details of the simulated and measured reflection coefficient, axial ratio, gain and radiation patterns are presented.

Widely Tunable Multiband Reconfigurable Patch Antenna for Wireless Applications [14]

A design of a low profile reconfigurable Microstrip patch antenna is presented. The antenna consists of four sub patches connected to one feed line, each sub-patch generates a single band. By placing a variable capacitor at the input of the sub-patches, the impedance matching frequency of the antenna can be tuned over a wide range starting from 0.92 GHz to 2.98 GHz with total tunability rang of 2060 MHz. The proposed antenna designed to operate in the Global System for Mobile communication (GSM900, 880-960 MHz)/ Digital Communication System (DCS1800, 1710-1880 MHz)/ Universal Mobile Telecommunication System (UMTS, 1920-2170 MHz)/ Wireless Local Area Network (WLAN, 2400-2483.5 MHz)/ and Worldwide Interoperability for Microwave Access (WiMAX, 2495-2700 MHz). The total size of the proposed antenna is 50 x 50 mm2 which is suitable for small wireless devices.

A Printed F-Shaped Dual-band Monopole Antenna for RFID and WLAN Applications [15]

Design of a simple Microstrip fed monopole patch antenna for the radio frequency identification (RFID) and wireless local area network (WLAN) is presented. The antenna has two different resonant paths (forming an F –shaped structure), supports two resonances at around 2.44 GHz and 5.18 GHz, which are reserved for RFID and WLAN applications. Effectively consistent radiation pattern and large impedance bandwidth has been observed.

Impedance bandwidth for -10 dB return loss in the 2.44 GHz and 5.18 GHz center frequency reaches 0.65 GHz (2.12 GHz to 2.77 GHz) and 0.59 GHz (4.91 GHz to 5.50 GHz) respectively. The proposed antenna is simple and compact in size providing broadband impedance matching, consistent radiation pattern and appropriate gain characteristics in the RFID and WLAN frequency range.

Omnidirectional Wrapped Microstrip Antenna for WLAN Applications in Laptop Computers [16]

An omnidirectional low profile microstrip antenna for WLAN applications in laptop computers is presented. By wrapping the patch antenna around the screen edge, very good omnidirectionality is achieved. The designed structure, fed by a microstrip inverted line, can be easily integrated inside the display plastic cover. An antenna prototype has been fabricated and tested. Good agreement has been obtained between simulations and experimental results. An adequate coverage of the whole 2.4 GHz ISM band has been achieved.

Design of High Gain Multiple U-Slot Microstrip Patch Antenna for Wireless System [17]

In this paper, a novel multi-slotted Microstrip patch antenna with high gain is presented and discussed. The design adopts contemporary techniques such as probe feeding and multi-slotted patch. These techniques can contribute to the enhanced performance of the antenna. The design also employs a novel shape patch. By integrating these techniques the proposed design offers low profile, high gain and compact antenna element. The maximum gain at the resonant frequency of 2.45GHz is 11.35dBi. The lowest return loss can be -34.49 dB at 2.45GHz.

The proposed design has a simple structure and a compact dimension of 87mm*51mm. The proposed design is suitable for particular wireless communication application such as Wi-Fi and WLAN.

A Compact Wideband Microstrip Antenna Operating In K Band Using A SIERF'INSKI GASKET Fractal Shaped Patch [18]

This paper proposes using a Fractal (Sierpinski gasket) patch to enhance the impedance bandwidth of microstrip antenna. A finite difference time domain (FDTD) method full wave simulator Fidelity is used to simulate the proposed antenna. Simulation results of a Sierpinski patch microstrip antenna and their comparison with simulation results of a corresponding conventional triangular patch antenna show that using a Sierpinski shaped patch greatly increases the impedance bandwidth of microstrip patch antenna (reaching nearly 40%). Using an inhomogeneous substrate along with the Sierpinski patch as well as the effect of the feedline location on both the antenna bandwidth and gain are considered.

A Triangular Patch Antenna with Bow Tie Aperture Coupling for Improved Ellipticity Bandwidth [19]

Improvement in ellipticity bandwidth with an equilateral triangular shaped microstrip patch antenna is analyzed in this paper. The triangular patch is electromagnetically coupled using two orthogonally oriented bow tie shaped apertures fed by a 3dB 90° hybrid for dual polarization operation. The radiating triangular patch has an optimized side length of 52.0 mm. The antenna is designed to transmit and receive the two differently circularly polarized wide band signals simultaneously with a single antenna. The use of a thick, low cost dielectric foam yields further improvement in bandwidth. A 2:1 impedance bandwidth of 38% and 3 dB axial ratio bandwidth of 23% has been achieved practically with the optimized geometry. An improvement of 7.16% in impedance bandwidth and 10.14% in ellipticity bandwidth is obtained over a patch of similar geometry with conventional rectangular shaped apertures. The use of dielectric foam makes the antenna light weight and low cost. The above features make it an ideal element for wide band application as required for Personal, Mobile Satellite and Wireless Communication Systems.

Conformal Patch Fed Stacked Triangular Dielectric Resonator Antenna for WLAN Applications [20]

A Stacked triangular dielectric resonator antenna (DRA) fed by a conformal patch is proposed for WLAN applications. In this paper, triangular shaped three resonators with same dielectric constant and different sizes are stacked to improve the gain, bandwidth and radiation performances of DRA. An increase in bandwidth is further achieved by using air gaps. This Stacked DRA is excited by a conformal patch connected to a microstrip line which is an effective feed mechanism to obtain wideband operation and is more efficient in energy coupling than other types of feeding techniques. This stacked triangular DRA is simulated using a CST microwave studio suiteTM 2010. The simulated results show that the proposed DRA achieves an impedance bandwidth of about 41% for VSWR less than 2, covering a frequency range from 4.0 GHz to 6.02 GHz. Its maximum gain is 7.98 dBi. The proposed antenna is suitable for wireless local area networks (WLAN) applications in 5-6 GHz frequency range. This stacked DRA exceeds the bandwidth requirements for the IEEE 802.11a wireless local area network (WLAN) applications (in the frequency range 5.15-5.35 GHz and 5.725-5.825 GHz) within a 2:1 VSWR. Parametric studies of the antennas with CST microwave based design data and simulated results are presented here.

A Triangular Microstrip Patch Antenna for Multi-band Applications [21]

A triangular microstrip patch antenna is proposed for multi-band applications. The proposed antenna is designed using a chip capacitor and T-shaped slit. Input impedance of the proposed antenna can be varied by changing the value of capacitor in the T-shaped slit. It can produce multi-resonant modes and yield return losses better than 16 dB in 1.97 ~ 2.16 GHz. The peak gains of the antenna present 2.95 and 3.15 dBi at both ends of the above frequency range. Details of the antenna design and experimental results are presented.

A Wideband Triangular Shaped Patch Antenna with folded shorting walls [22]

Microstrip antennas offer a number of attractive advantages and some designs of enhancing the bandwidth were proposed in the literature, such as adding parasitic patches, or using Lshaped probe coupling. Techniques of shorting pin and shorting wall are used to reduce the patch size or to get good matching in the structures.F or example, h [I], a new approach to bandwidth enhancement by using a pair of shorting pin and shorting wall was introduced which achieves 20% bandwidth In this paper, a folded shorting wall is introduced to the antenna structure to take the place of the pair of shorting pin and shorting wall and achieve bandwidth enhancement. Furthermore, by modifying the shape of the patch, a very wideband patch antenna has been achieved. 30.5% bandwidth of simulated result and 28.1% bandwidth of measured result have been achieved, which represents an enhancement of 54.5% compared to the design in [1]. The main parameters that affect the antenna bandwidth performance are given in details. The effect of the shorting technique for a quarter-wave patch is studied and a modified patch shape and shorting wall is presented. With the folded shorting wall, a stable gain of 5.5dBi is obtained over the matching bandwidth. Radiation patterns are presented. Thus a folded shorting wall, a suitable patch geometry appears to be a better bandwidth enhancement technique than the previous method of utilizing a pair of shorting wall and shorting pin.

Dual band Pentagonal Microstrip Antenna for Wi-Fi Applications [23]

The proposed antenna is formed by a patch rectangular antenna with an inner pentagonal one, built on FR-4, due its low cost and availability. There were considered 2.4 and 5.8 GHz as the operation frequencies, considering linear polarization in order to apply them to Wi-Fi equipments. The pentagonal patches were designed considering them as equivalents with the corresponding circular resonators. The simulations are realized using CADFEKO, software based on the Moment Method (MoM). The proofs were realized considering the designed antennas as replacement ones on a router. Simulated input return loss show a good agreement with the operation frequencies design. It has been demonstrated that the dual antenna operate satisfactorily in the 2.4 and 5.8 GHz frequency ranges, showing its feasibility to use it for Wi-Fi applications. Experimental results are compared to predictions from a software package confirming monopolar radiation in two bands at 2.4 GHz and 5.8 GHz.

Chapter 4

DESIGN OF DUAL BAND MICROSTRIP ANTENNA FOR WLAN APPLICATIONS USING DIFFERENT SHAPED PATCH

In this chapter three microstrip patch antennas with three different shapes of patch are designed .These three antennas are designed for dual band WLAN applications which resonate at 2.4GHz and 5.2GHz.For designing these antennas coaxial feeding technique is used here. The return loss and smith chart have also been studied.

4.1 Design procedure of Microstrip Patch Antenna

The arrangement of an arbitrary shaped patch microstrip antenna is given in Figure 4.1. It consists of patch, substrate, ground plane and feeding point. A patch is a two-dimensional antenna element, which is often rectangular in shape. It is of a very thin thickness of metallic strip on top of a material known as the substrate with thickness h ($h \ll \lambda o$, usually $0.003\lambda o \leq h \leq 0.05\lambda o$, where λo is free space wavelength) above a ground plane.[2]

For rectangular patch, the length L of the element is usually $\lambda o/3 < L < \lambda o/2$. The strip (patch) and the ground plane are separated by a dielectric (substrate).

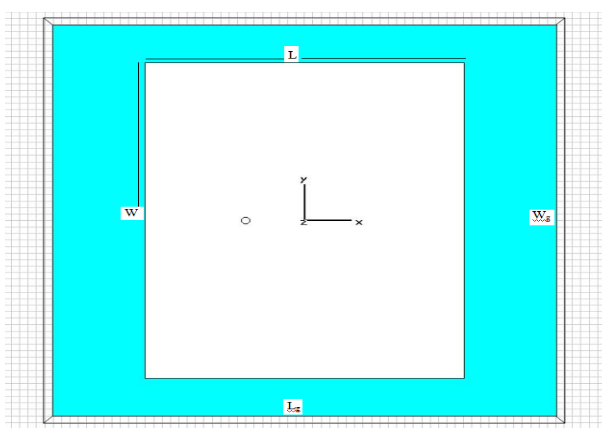


Figure 4.1: Layout of Patch Antenna

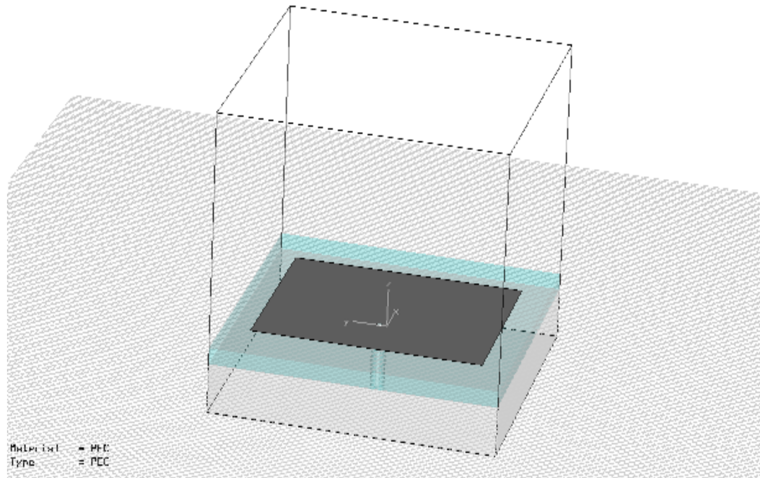


Figure 4.2 Structural View of Patch Antenna

In the typical design procedure of Microstrip patch antenna, three essential parameters are :

- **Frequency of operation (fr):** The resonant frequency of the antenna must be selected appropriately. The frequency ranges and the bandwidth requirement for various wireless applications are shown in the table 1.1. The resonant frequencies selected for my design is 2.45 GHz and 5.2GHz for WLAN

- **Dielectric constant of the substrate (ε_r):** The dielectric constant of substrate material plays an important role in the patch antenna design. A substrate with a high dielectric constant reduces the dimensions of the antenna but it also affects the antenna performance. So, there is a trade-off between size and performance of patch antenna.

- **Height of dielectric substrate (h):** For the Microstrip patch antenna to be used in wireless communication systems, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate should be less.

After the proper selection of above three parameters, the next step is to calculate the radiating patch width and length.

4.2 Design procedure

The design procedure of single band microstrip patch antenna using rectangular patch is carried out step by step[1,2] is given below;

(a) Substrate Selectivity: Selection of suitable substrate of appropriate thickness is the first step in the design procedure of any microstrip antenna. Bandwidth and radiation efficiency increase with substrate thickness. The radiation efficiency of the microstrip antenna depends largely on the permittivity of the dielectric. It affects both the width, in turn the characteristic impedance and the length resulting in an altered resonant frequency and reduced transmission efficiency .

(b) Calculation of width of patch:

The width of the antenna is calculated by equation

$$w = \frac{1}{2 f_r \sqrt{\varepsilon_o \mu_o}} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{4.1}$$

(c) Calculation of effective dielectric constant:

The effective dielectric is calculated by equation

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[1 + \frac{12h}{w} \right]^{-\frac{1}{2}} \tag{4.2}$$

(d) Calculation of the effective length:

The effective length is calculated using equation

$$f_r = \frac{1}{2L\sqrt{\varepsilon_r \varepsilon_o \mu_o}} = \frac{v_o}{2L\sqrt{\varepsilon_r}} \tag{4.3}$$

(e) Calculation of the length extension:

The length extension is calculated using equation

$$\frac{\Delta L}{h} = .412 \frac{\left(\varepsilon_{reff} + 3\right)\left(\frac{W}{h} + .264\right)}{\left(\varepsilon_{reff} - .258\right)\left(\frac{W}{h} + .8\right)}$$

(f) Calculation of actual length of patch:

The actual length is obtained by equation,

$$L_{eff} = L + 2\Delta L \tag{4.5}$$

(g) Calculation of the ground plane dimensions:

The transmission line model even though is applicable to infinite ground planes only but for practical considerations, a finite ground plane is used. However, size of ground plane should be greater than the patch dimensions by approximately six times the substrate thickness all around the periphery so that results are similar to the one using infinite ground plane. The ground plane dimensions are calculated as:

$$L_g = 6h + L \tag{4.6}$$

$$W_g = 6h + W \tag{4.7}$$

Where,

h = substrate thickness

L = length of patch

L_{eff} = effective length

W = width of patch

c = speed of light

f_r = resonant frequency

ε_r = relative permittivity

ε_{reff} =effective permittivity

L_g =length of ground

W_g =width of ground\

(h) Coaxial feed position:

The inner conductor of the coax is connected to the radiation patch and the outer conductor to ground plane. The feed point should be near one of the two radiating edges . *Rin* for coaxial is given by equation

$$R_{in}=R_r\cos^2(\pi Yo/L) \qquad (4.8)$$

Where,

R_{in}=input resistance

$R_{r=}$radiation resistance of antenna.

To design the single band mictostrip patch antennas using triangular and pentagonal shaped patches the parameters of substrate and the ground can be calculated as same as that for rectangle patch antenna but the parameter of the patch is changed. To have the triangular shaped patch we used the cylindrical patch and made three segments which gave us an equilateral triangular shaped patch.

Similarly to have pentagonal patch, we used the cylindrical patch and made five segments which gave us an equilateral pentagonal shaped patch.

The length of the equilateral triangle and the pentagon patches can be changed by changing the radius of the cylinder used for designing patch.

To have the antenna resonating at more than one frequency we go for multi banding. One of the easy and efficient method of achieving multi banding is cutting slots in the patch. The length and position of the slots can be changed to obtain the microstrip patch antennas resonating at more than one frequencies. In this way we can have the dual or triple band antennas.

4.3 Design of Coaxial fed dual band microstrip antenna for WLAN application using rectangular patch

To design dual band antenna first of all we calculate the parameters for single band antenna and then cut the slots of appropriate length at appropriate position to make it dual band. In our design firstly we calculate the parameters of the microstrip patch antenna to resonate at 2.4GHz by using the equations 4.1-4.8 taking height of substrate (h)=3.048mm and dielectric constant(ε)=2.2. The parameters are:

Size of substrate = 55.78×64.4 mm

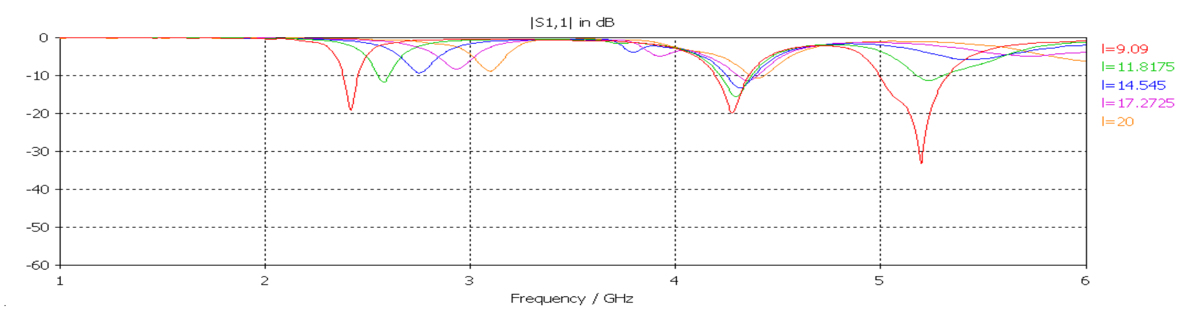
Size of ground = 55.78×64.4 mm

Size of patch = 37.6×45 mm

After getting the desired simulated results for 2.4GHz frequency, we went for cutting slot in the patch to make it resonate at another frequency also. Before getting the optimum simulated results in terms of return loss, resonant frequencies, bandwidth and impedance matching we have done the parametric simulation study of the designed antennas.

4.3.1 Parametric study of coaxial fed dual band microstrip antenna for WLAN application using rectangular patch

(a)Effect of variation in length of the patch: It is observed from fig.4.3 that the return loss increases as the length of the patch decreases. Also the resonant frequencies increases with the decrease in the length of the patch.

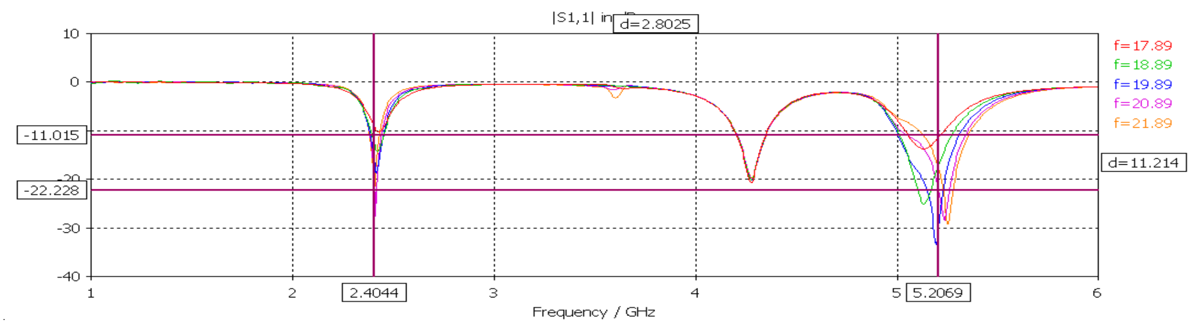


Note: l is taken as the min. coordinate of the length of the patch

Fig 4.3 Effect of Patch length (rectangular patch antenna)

From the observations from the fig.4.3 it is clear that l=9.09mm is best for our antenna to resonate at 2.4GHz and 5.2GHz.

(b)Effect of feed point location: From the fig 4.4 it is observed that if the location of the feed point is changed, the resonant frequency as well as the return loss will change.

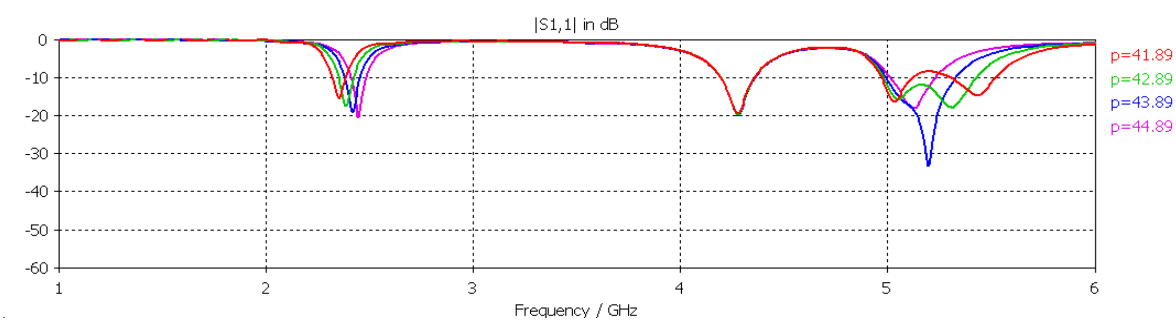


Note: f is taken as the x coordinate of feed(x,y)

Fig 4.4 Effect of feed point location (rectangular patch antenna)

From the observations from the fig.4.4 it is clear that f=19.89 mm is best for our antenna to resonate at 2.4GHz and 5.2GHz.

(c)Effect of slot position: The position of the slot plays an important role in the design of the dual band microstrip patch antennas. It is observed from the fig 4.5 that as the position of the slot changes ,the return loss and the resonant frequency are greatly effected.



Note: p is taken as the x(min) coordinate along the length of patch

Fig 4.5 Effect of slot position (rectangular patch antenna)

From the observations from the fig.4.5 it is clear that p=43.89mm is best for our antenna to resonate at 2.4GHz and 5.2GHz

After studying the effect of various parameters we got the optimum values of the parameters for our design. The geometry of proposed antenna which is coaxial fed for WLAN applications is depicted in Table 4.1. The dimensions of the designed antenna with coaxial feed are:

Table 4.1:- Dimension of the proposed antenna using rectangular patch

Ground size	55.78×64.4 mm
Substrate size	55.78×64.4 mm
Patch size	37.6×45 mm
Slot size	1×30 mm
Feed point location(x,y)	19.89,32.2
ε_r	2.2

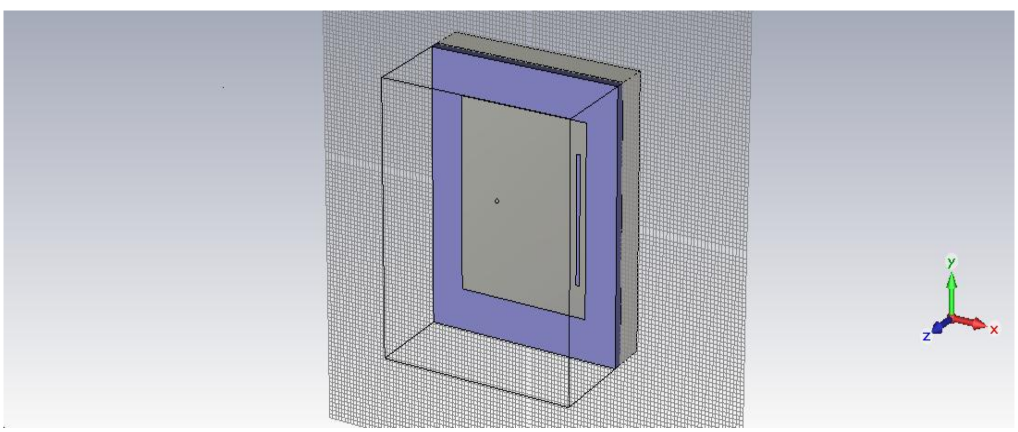


Fig 4.6 Structural view of the rectangular patch antenna

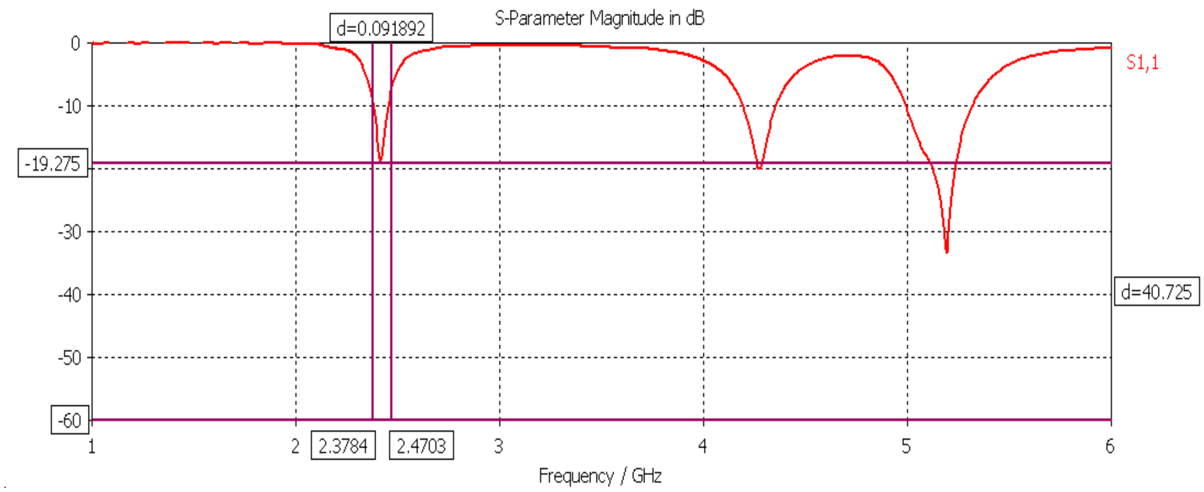


Fig 4.7(a) Simulated Return Loss[s_{11}] of the Dual Band Rectangular patch antenna

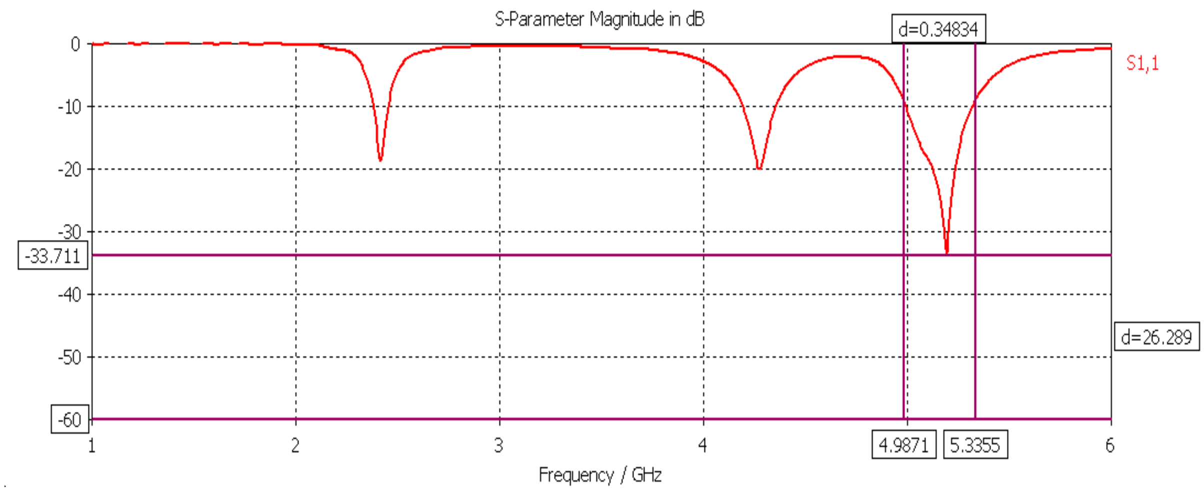


Fig 4.7(b) Simulated Return Loss[s_{11}] of the Dual Band Rectangular patch antenna

4.7(a) shows that proposed antenna is having return loss of -19.275 dB at 2.4GHz frequency and the bandwidth achieved is 91.89MHz . Fig 4.7(b) shows that proposed antenna is having return loss of -33.711 dB at 5.2GHz frequency and the bandwidth achieved is 348.34MHz . Fig 4.8 shows the smith chart representation of the proposed antenna.

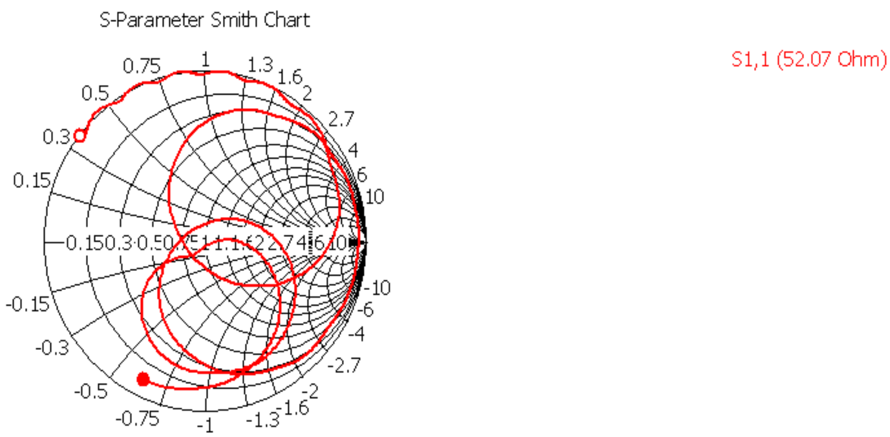


Fig 4.8 Smith chart presentation of the rectangular patch antenna

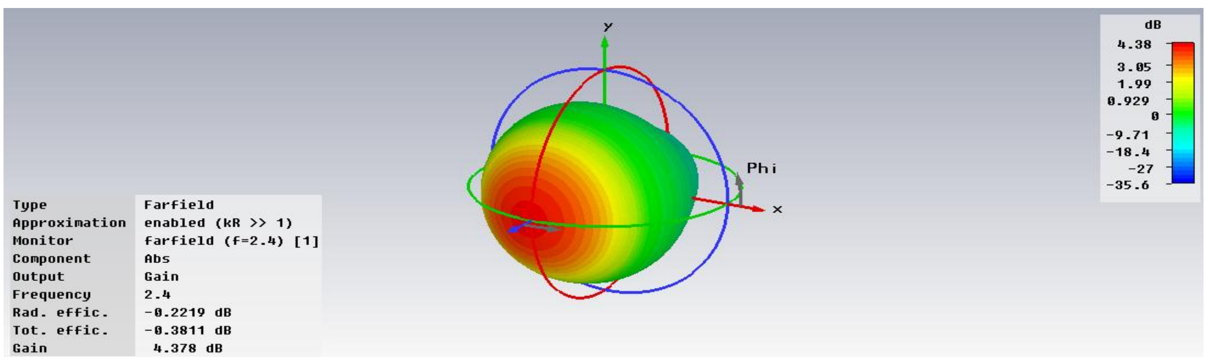


Fig 4.9 (a) Radiation pattern of rectangular patch antenna at 2.4 GHz

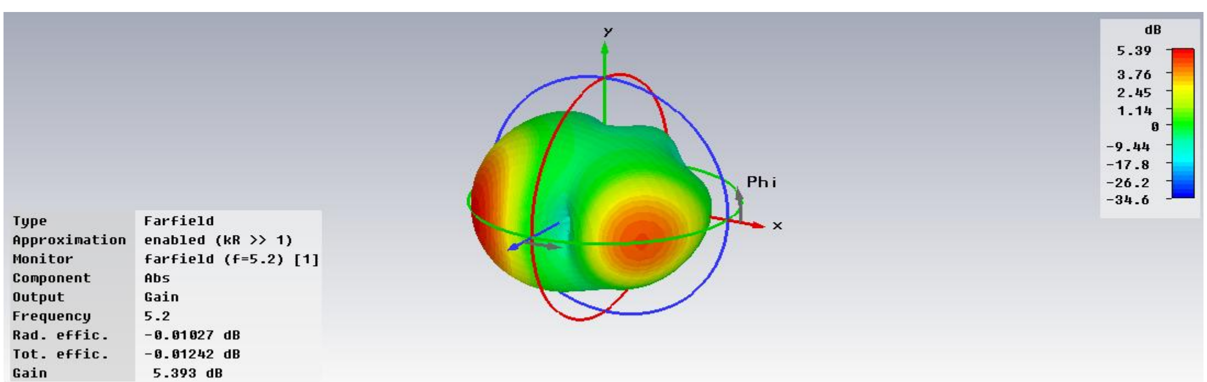


Fig 4.9 (b) Radiation pattern of rectangular patch antenna at 5.2 GHz

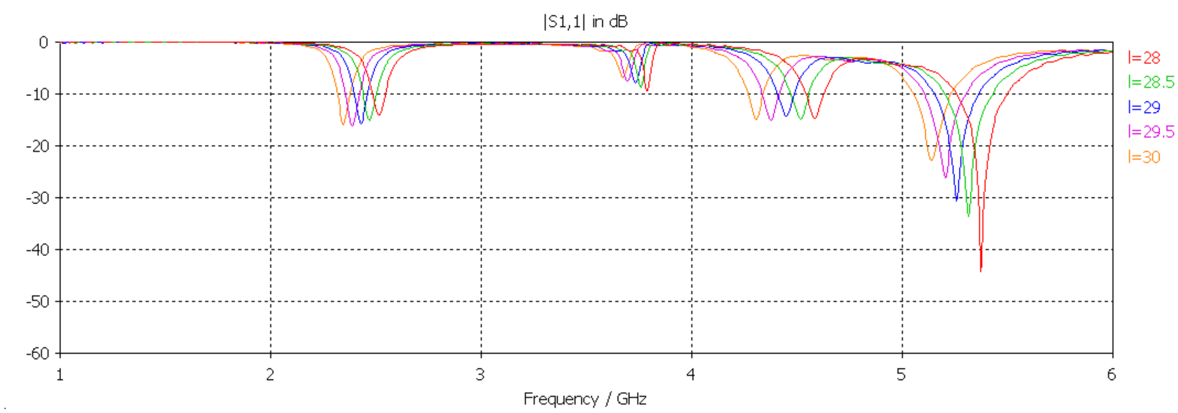
Fig.4.9(a,b) show the radiation patterns of the dual band rectangular patch antenna at 2.4GHz and 5.2GHz respectively. The gain is 4.378dB at 2.4GHz and 5.393dB at 5.2GHz.

4.4 Design of Coaxial fed dual band microstrip antenna for WLAN applications using triangular patch

To design the triangular shaped patch we have used a cylindrical patch cut in to three segments which gave us an equilateral triangular patch. The radius of the cylinder is varied to vary the dimensions of the triangular patch.

4.4.1 Parametric study of coaxial fed dual band microstrip antenna for WLAN application using triangular patch

(a)Effect of variation in length of the patch: It is observed from fig.4.10 that the return loss increases as the length of the patch decreases. Also the resonant frequencies increases with the decrease in the length of the patch.

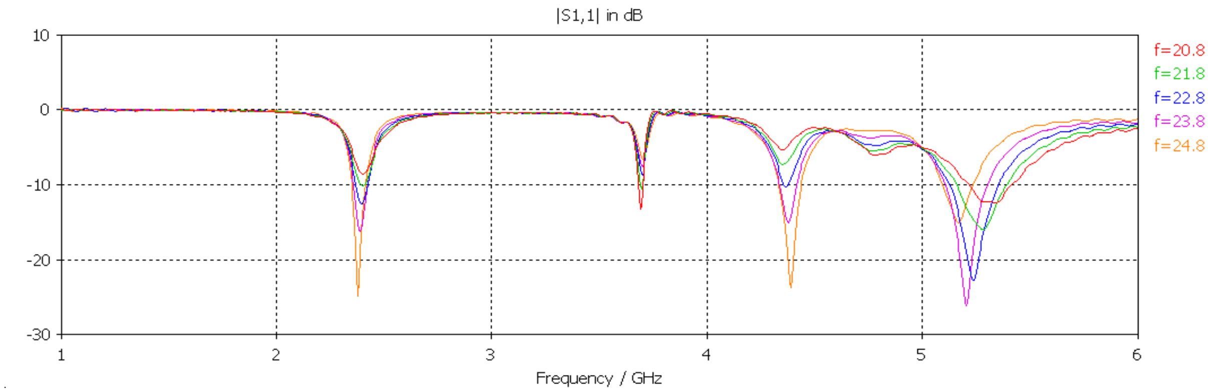


Note: l is taken as the radius of the cylinder cut in 3 segments to make triangular patch

Fig 4.10 Effect of Patch length (triangular patch antenna)

From the observations from the fig.4.10 it is clear that l=29 mm is best for our antenna to resonate at 2.4GHz and 5.2GHz

(b)Effect of feed point location: From the fig 4.11 it is observed that if the location of the feed point is changed, the resonant frequency as well as the return loss will change.

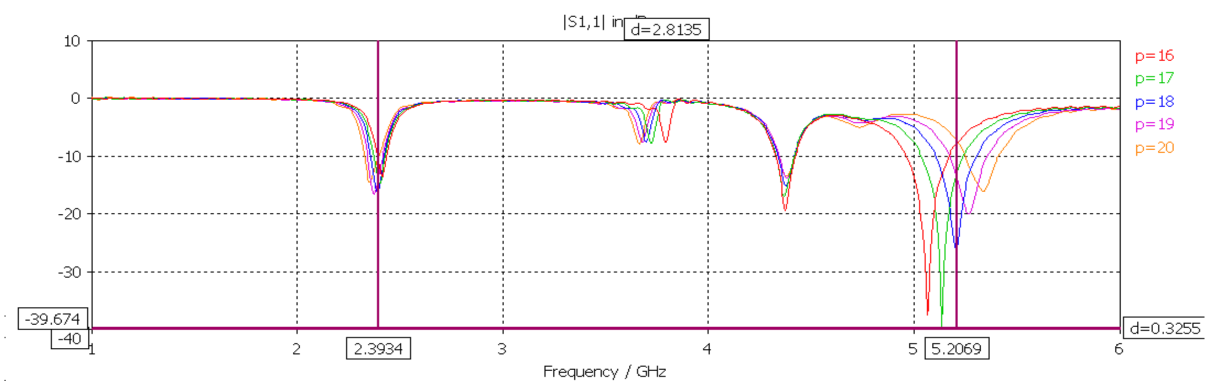


Note: f is taken as the x coordinate of feed(x,y)

Fig 4.11 Effect of feed point location(triangular patch antenna)

From the observations from the fig.4.11 it is clear that f=23.8 mm is best for our antenna to resonate at 2.4GHz and 5.2GHz.

(c)Effect of slot position: The position of the slot plays an important role in the design of the dual band microstrip patch antennas. It is observed from the fig 4.12 that as the position of the slot changes ,the return loss and the resonant frequency are greatly effected.



Note: p is taken as the y(min) along the width of the substrate

Fig 4.12 Effect of slot position(triangular patch antenna)

From the observations from the fig.4.12 it is clear that p=18 mm is best for our antenna to resonate at 2.4GHz and 5.2GHz

The geometry of proposed antenna which is coaxial fed for WLAN applications is depicted in Table 4.2 The dimensions of the designed antenna with coaxial feed are:

Table 4.2:- Dimension of the proposed antenna using triangular patch

Ground size	60×64 mm
Substrate size	60×64 mm
Patch size	50.22 mm (side of equilateral triangle)
Slot size	28×1 mm
Feed point location(x,y)	23.8,32
ε_r	2.2

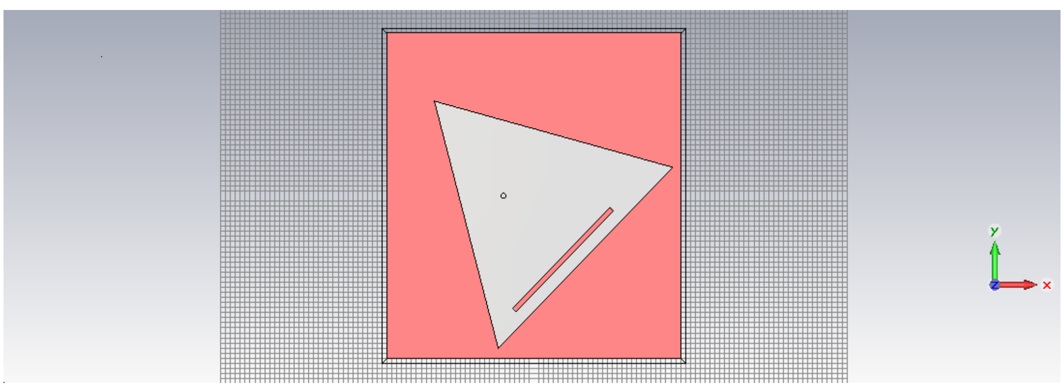


Fig 4.13 Structural view of the triangular patch antenna

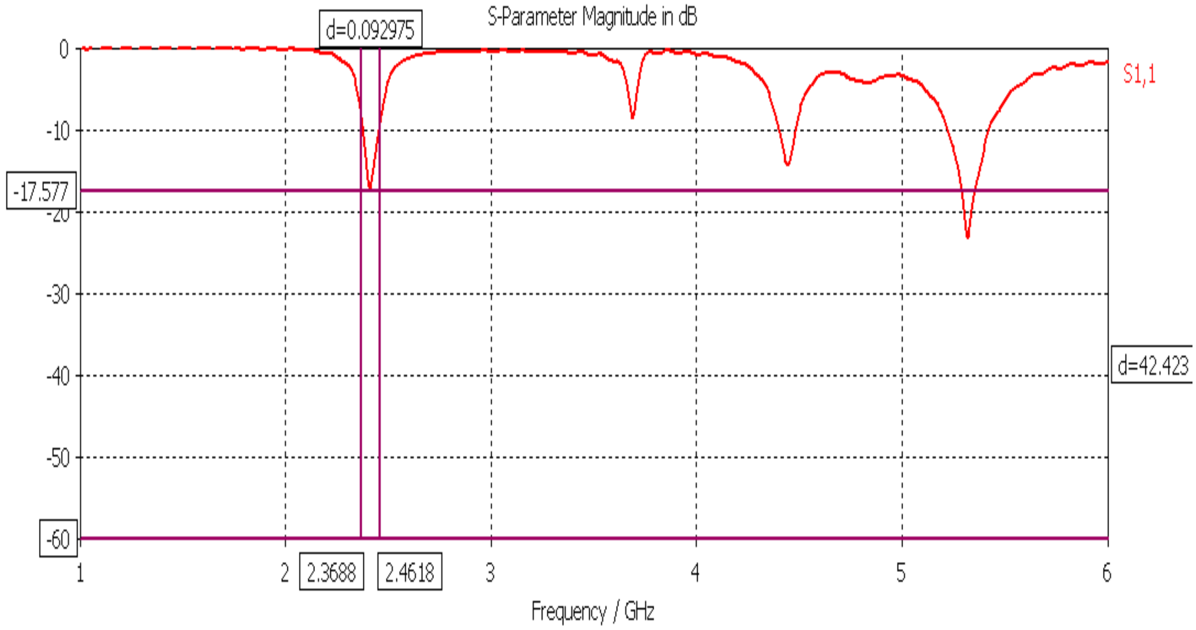


Fig 4.14(a) Simulated Return Loss[s_{11}] of the Dual Band Triangular patch antenna

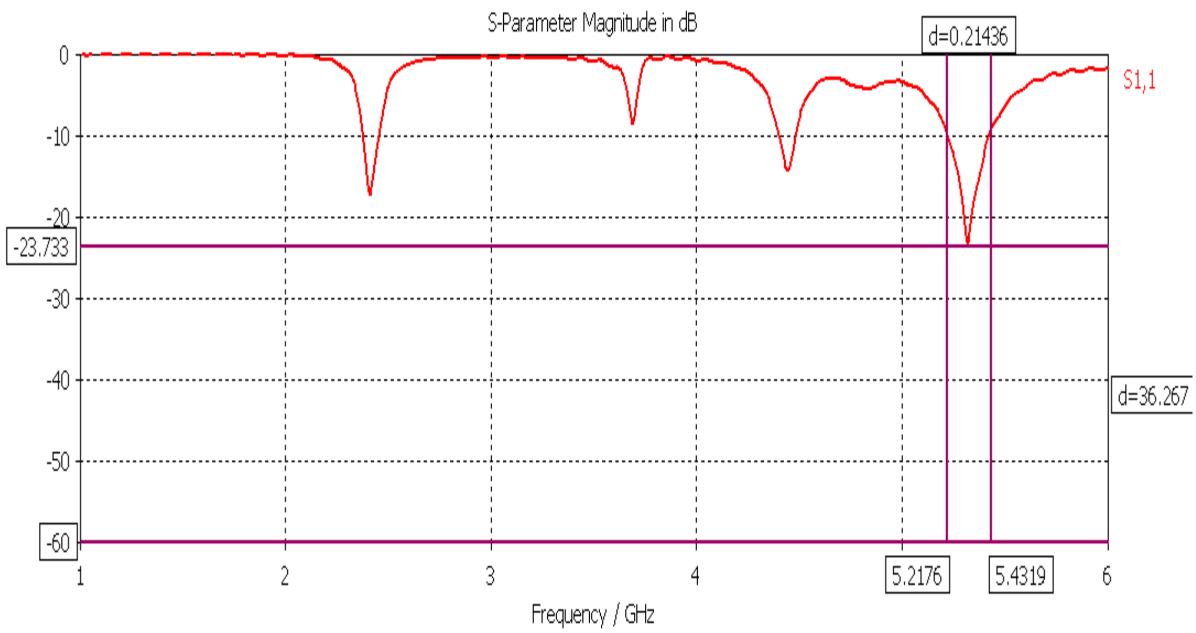


Fig 4.14(b) Simulated Return Loss[s_{11}] of the Dual Band Triangular patch antenna

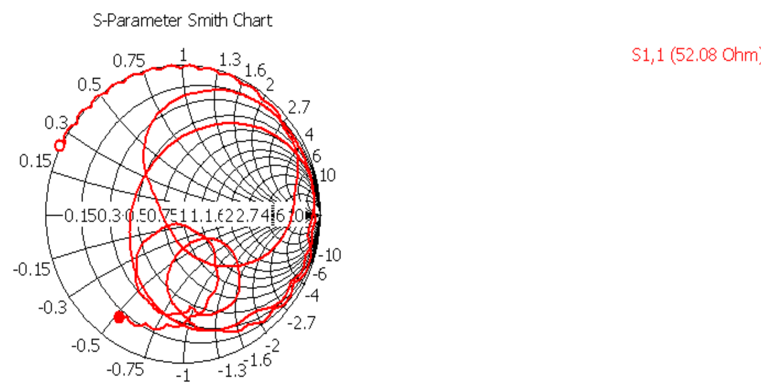


Fig 4.15 Smith chart presentation of the Triangular patch antenna

Fig 4.14(a) shows that proposed antenna is having return loss of -17.577 dB at 2.4GHz frequency and the bandwidth achieved is 92.975MHz . Fig 4.14(b) shows that proposed antenna is having return loss of -23.733 dB at 5.2GHz frequency and the bandwidth achieved is 214.36 MHz . Fig 4.15 shows the smith chart representation of the proposed antenna.

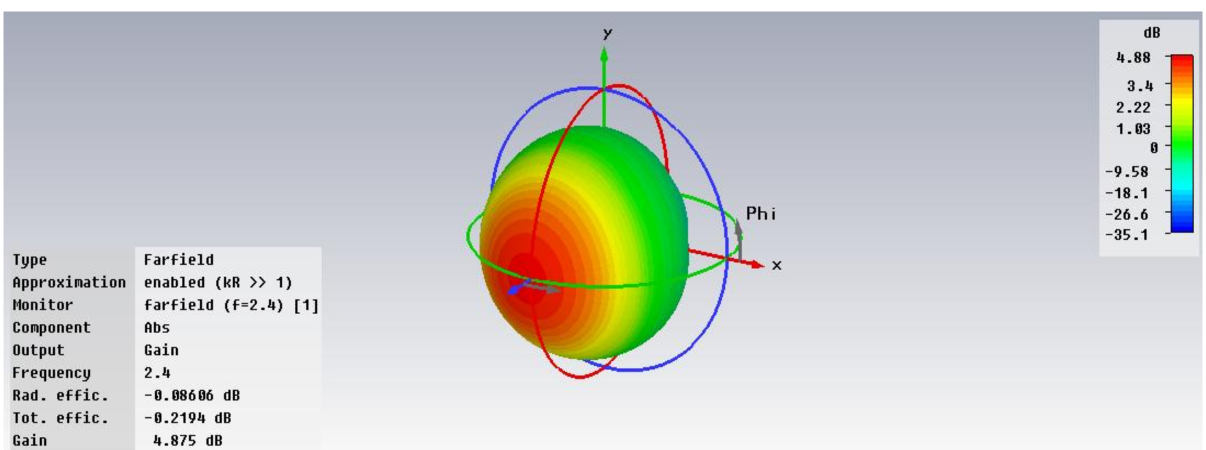


Fig 4.16(a) Radiation pattern of Triangular patch antenna at 2.4 GHz

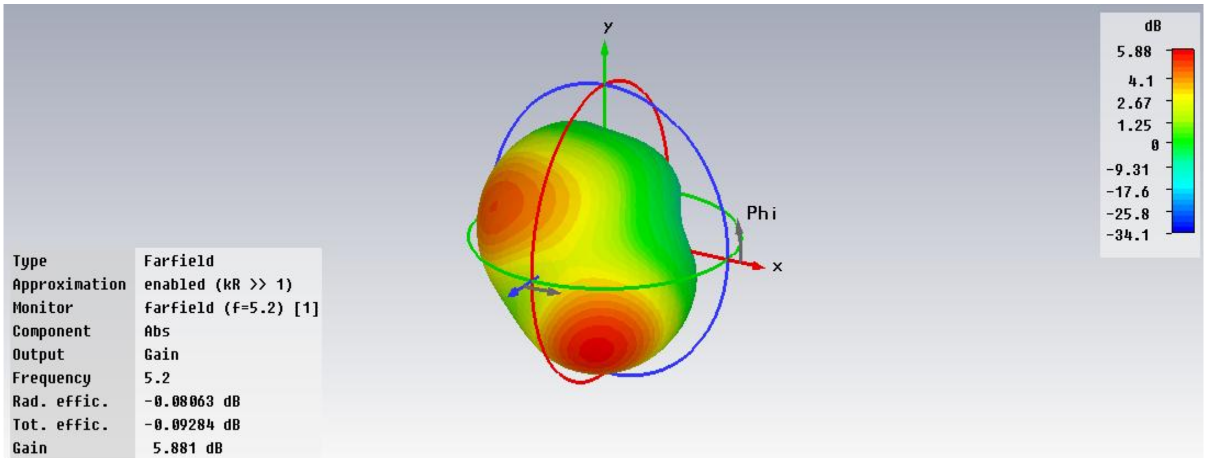


Fig 4.16 (b) Radiation pattern of Triangular patch antenna at 5.2 GHz

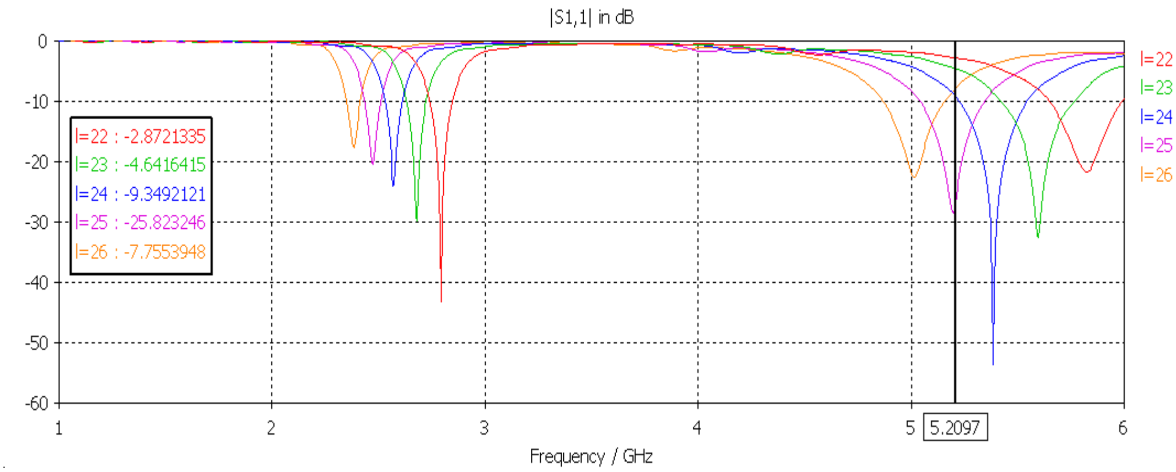
Fig.4.16 (a,b) show the radiation patterns of the dual band triangular patch antenna at 2.4GHz and 5.2GHz respectively. The gain is 4.875dB at 2.4GHz and 5.881dB at 5.2GHz.

4.5 Design of Coaxial fed dual band microstrip antenna for WLAN application using pentagonal patch

To design the pentagon shaped patch we have used a cylindrical patch cut in to five segments which gave us an equilateral pentagonal patch. The radius of the cylinder is varied to vary the dimensions of the pentagonal patch.

4.5.1 Parametric study of coaxial fed dual band microstrip antenna for wlan application using pentagonal patch

(a)Effect of variation in length of the patch: It is observed from fig.4.17 that the return loss increases as the length of the patch decreases. Also the resonant frequencies increases with the decrease in the length of the patch.

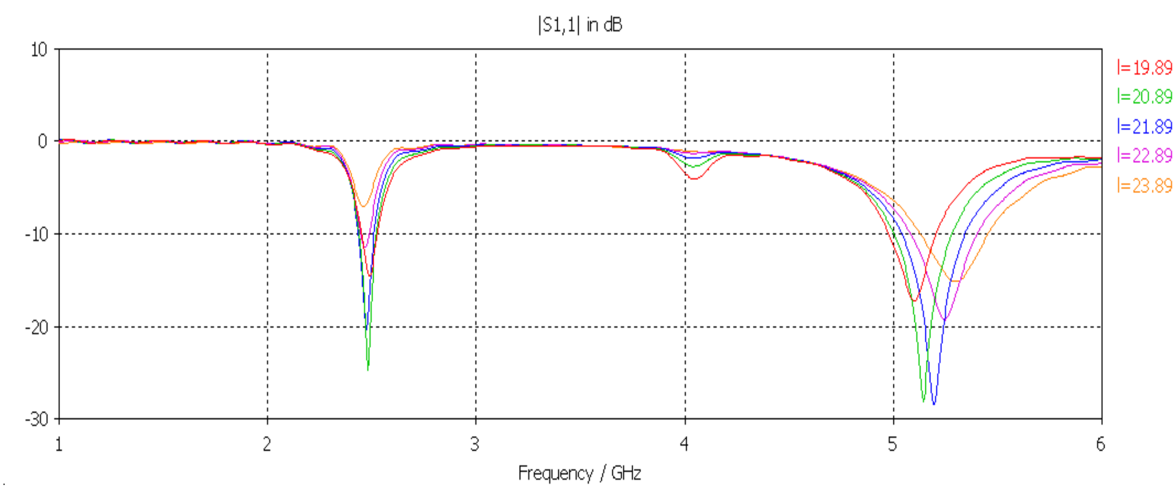


Note: l is taken as the radius of the cylinder cut in five segments to make pentagonal patch

Fig 4.17 Effect of Patch length(pentagonal patch antenna)

From the observations from the fig.4.17 it is clear that l=25 mm is best for our antenna to resonate at 2.4GHz and 5.2GHz.

(b)Effect of feed point location: From the fig 4.18 it is observed that if the location of the feed point is changed, the resonant frequency as well as the return loss will change.

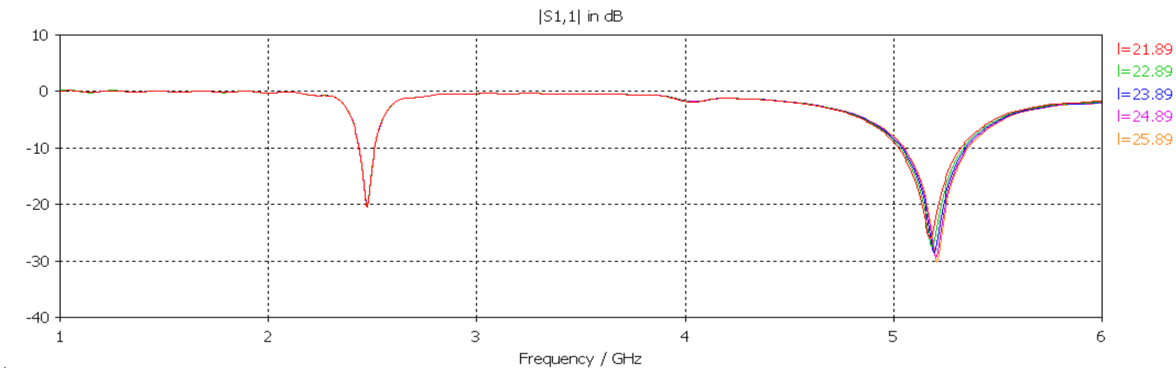


Note: f is taken as the x coordinate of feed(x,y)

Fig 4.18 Effect of feed point location(pentagonal patch antenna)

From the observations from the fig.4.18 it is clear that f=21.89 is best for our antenna to resonate at 2.4GHz and 5.2GHz.

(c)Effect of slot position: It is observed from the fig 4.19 that in pentagon patch antenna, length of the slot has slight effect on the return loss and the resonant frequency.



Note: l is taken as the x(min) along the length of the substrate

Fig 4.19 Effect of slot position(pentagonal patch antenna)

From the observations from the fig.4.19 we chose l=23.89 for our antenna to resonate at 2.4GHz and 5.2GHz.

The geometry of proposed antenna which is coaxial fed for WLAN applications is depicted in Table 4.3 the dimensions of the designed antenna with coaxial feed are:

Table 4.3:- Dimension of the proposed antenna using pentagonal patch

Ground size	55.78×64.4 mm
Substrate size	55.78×64.4 mm
Patch size	29.389 mm (length of each side of equilateral pentagon)
Slot size	8×1 mm
Feed point location(x,y)	21.89,32.2
ε_r	2.2

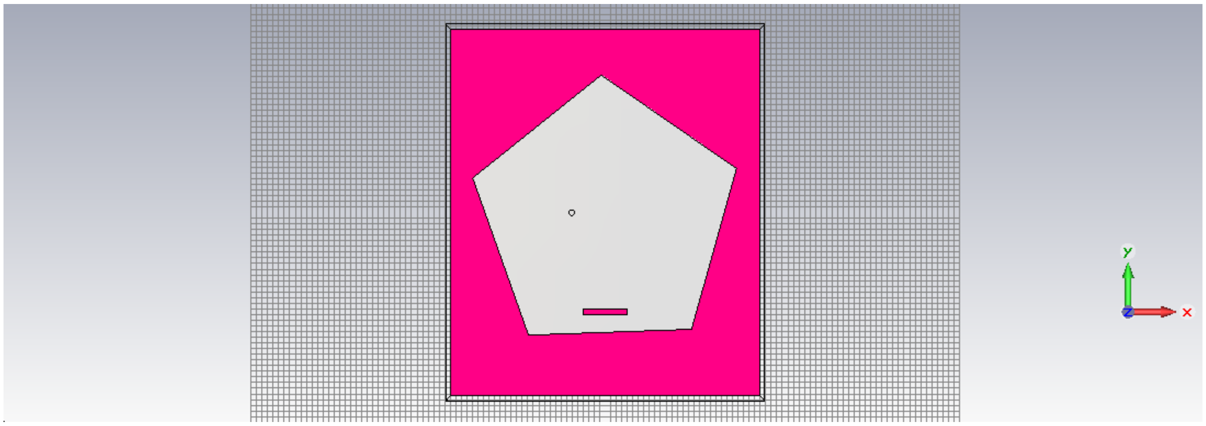


Fig 4.20 Structural view of the Pentagonal patch antenna

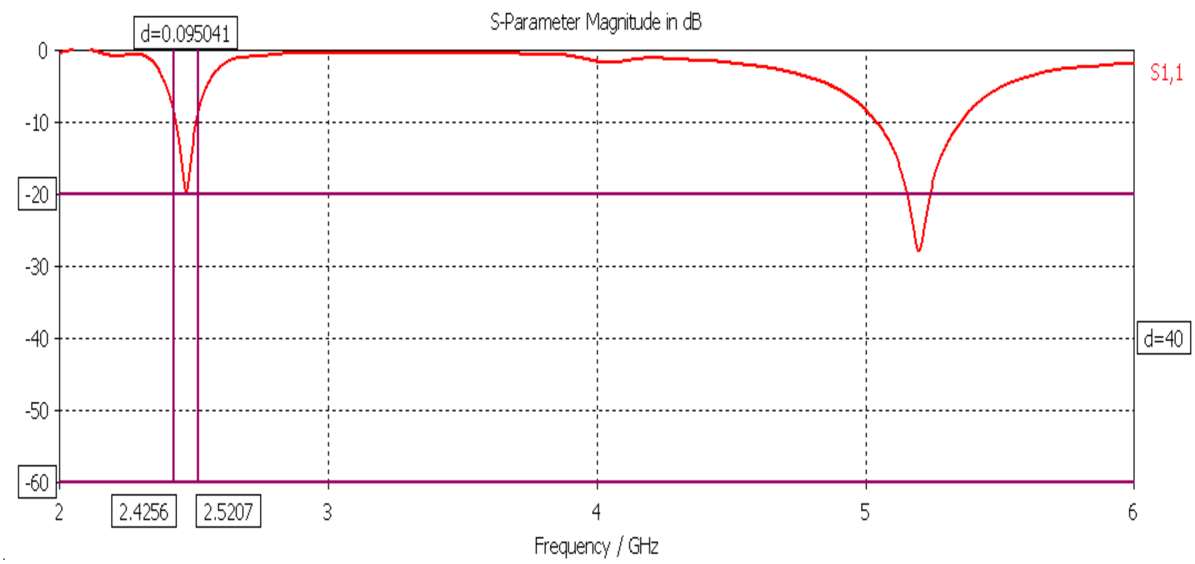


Fig 4.21(a): Simulated Return Loss[s_{11}] of the Dual Band Pentagonal patch antenna.

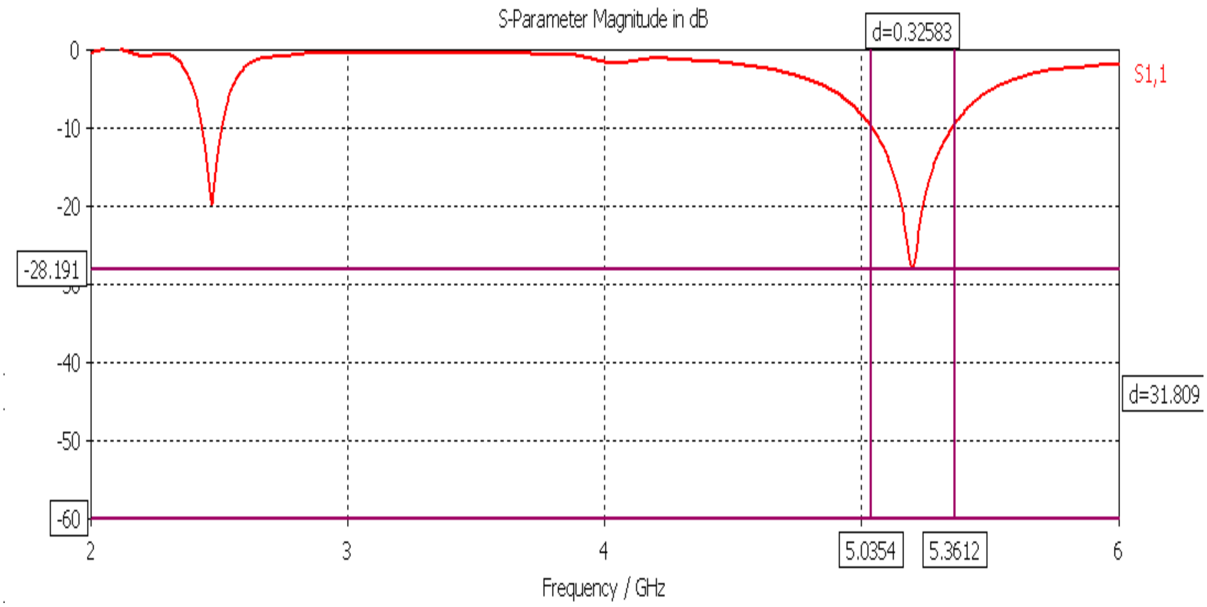


Fig 4.21(b) Simulated Return Loss[s_{11}] of the Dual Band Pentagonal patch antenna

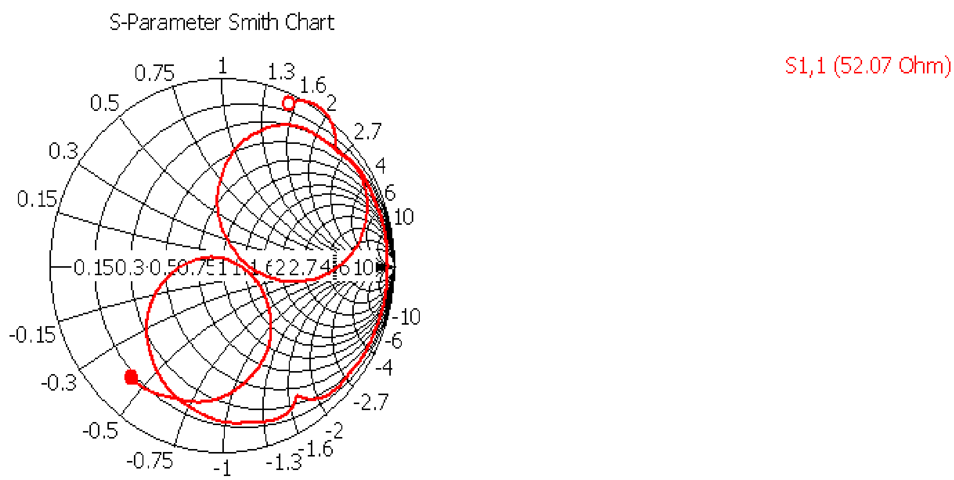


Fig 4.22Smith chart presentation of the Pentagonal patch antenna

Fig 4.21(a) shows that proposed antenna is having return loss of -20dB at 2.4GHz frequency and the bandwidth achieved is 95.04MHz . Fig 4.21(b) shows that proposed antenna is having return loss of -28.191dB at 5.2GHz frequency and the bandwidth achieved is 325.83MHz . Fig 4.22 shows the smith chart representation of the proposed antenna.

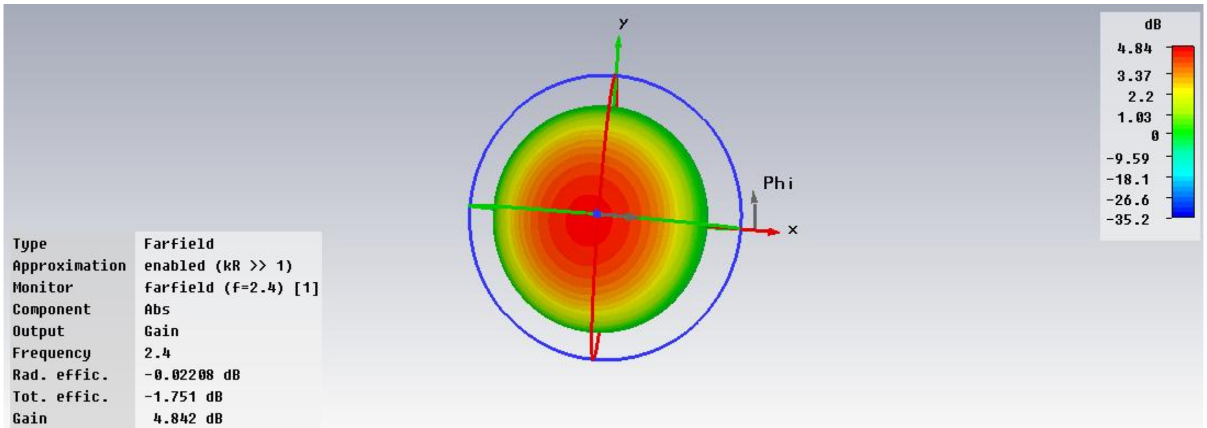


Fig 4.23(a) Radiation pattern of pentagonal patch antenna at 2.4 GHz

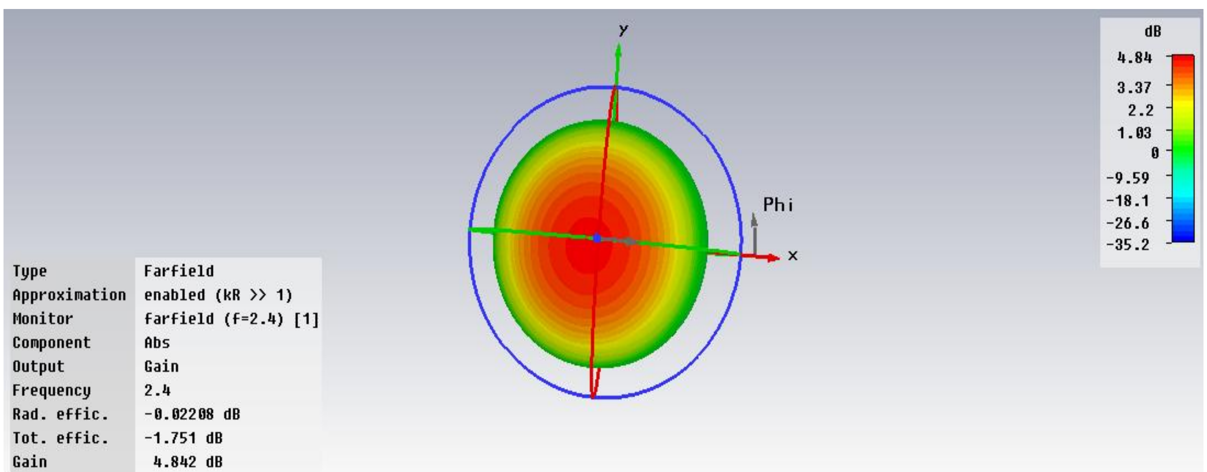
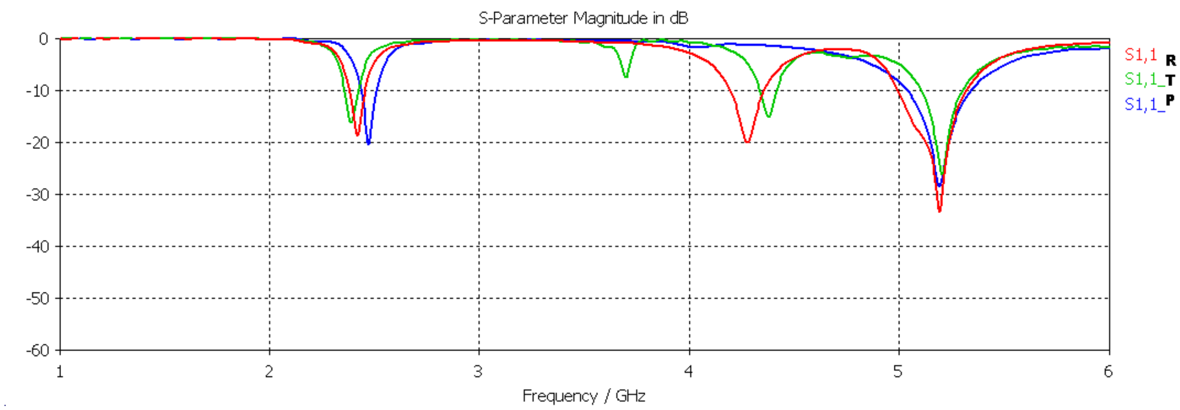


Fig 4.23(b) Radiation pattern of pentagonal patch antenna at 5.2 GHz

Fig.4.23 (a,b) show the radiation patterns of the dual band pentagonal patch antenna at 2.4GHz and 5.2GHz respectively. The gain is 4.842dB at both 2.4GHz and 5.2GHz.

The composite simulated results of frequency versus return loss for rectangular, triangular and pentagonal patch antennas is shown in the fig.4.24.



Note: R is for rectangular patch, T is for triangular patch and P is for pentagonal patch

Fig.4.24 Composite simulated results of designed antennas

4.6 Comparison of simulated antennas

From the above results which are simulated using “CST Microwave studio V9”, the comparison of the three antennas using three different shapes of patches for WLAN applications, is shown in the table 4.4. The table shows the return loss and the bandwidth obtained at 2.4GHz and 5.2GHz frequencies.

Table 4.4 Comparison of designed antennas

SHAPE OF PATCH	FREQUENCY	RETURN LOSS	BANDWIDTH
Rectangle	2.4GHz	-19.275dB	91.89MHz
	5.2GHz	-33.711dB	348.34MHz
Triangle	2.4GHz	-17.577dB	92.975MHz
	5.2GHz	-23.733dB	214.36MHz
Pentagon	2.4GHz	-20dB	95.04MHz
	5.2GHz	-28.191dB	325.83MHz

Chapter 5

FABRICATION STEPS OF THE MICROSTRIP PATCH ANTENNA

This chapter describes the entire procedure for fabrication of a microstrip patch antenna. Some fabricated antennas are also presented that are designed and simulated in chapter 5.

5.1 Fabrication process:

There are various steps followed when we fabricate an antenna. This can be shown via a flow chart:

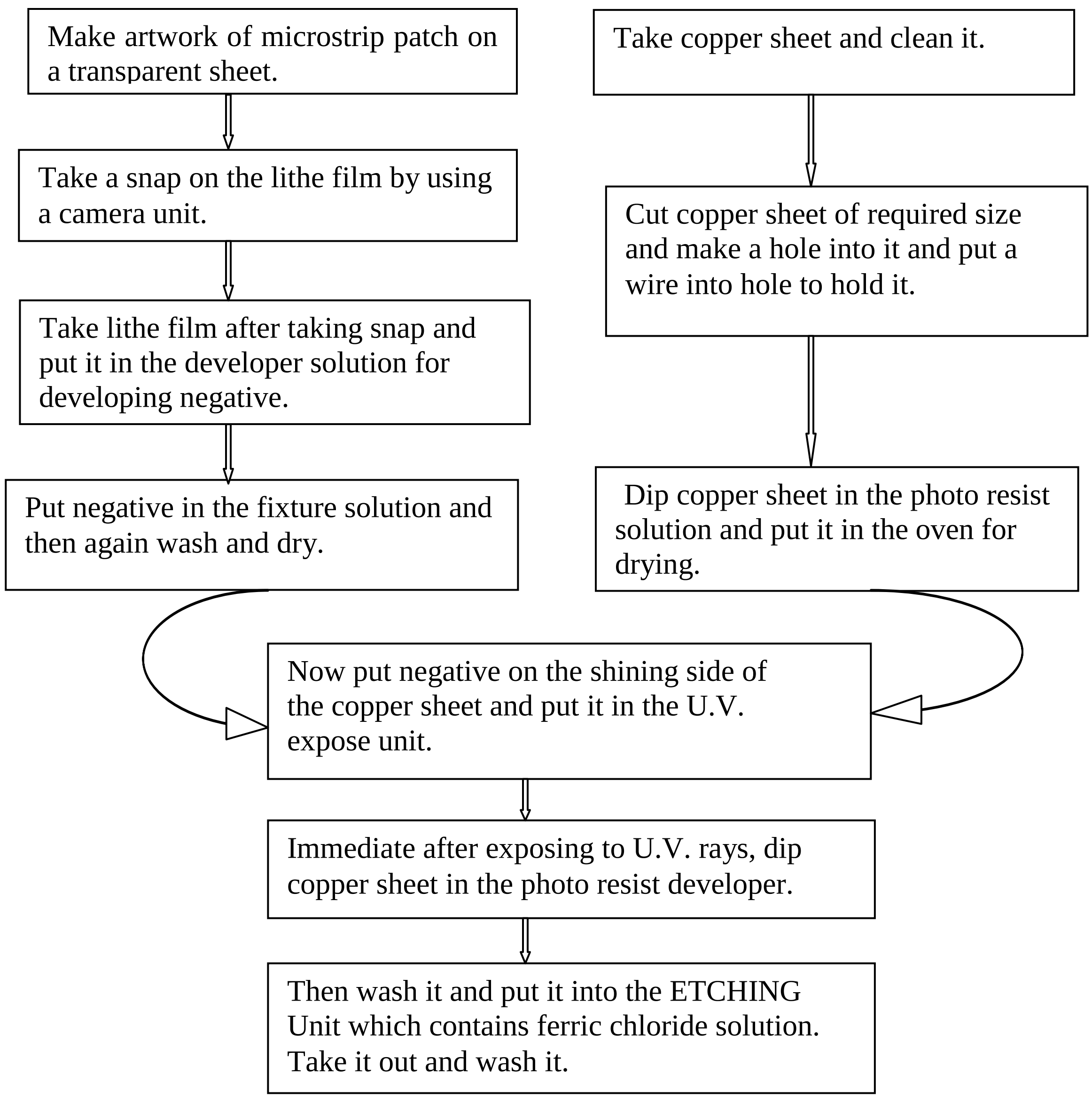


Fig 5.1: Fabrication Steps

5.2 Some fabricated microstrip patch antenna:

Fabrication of Microstrip antenna simulated above is carried out at PCB FABRICATION LAB at Thapar University, Patiala. Images of the fabricated microstrip patch antennas of three different shaped patches for WLAN application is shown below in figure 5.2, figure 5.3 and figure 5.4. Images for setup of PCB FABRICATION lab is also shown in figure 5.5-figure 5.10.

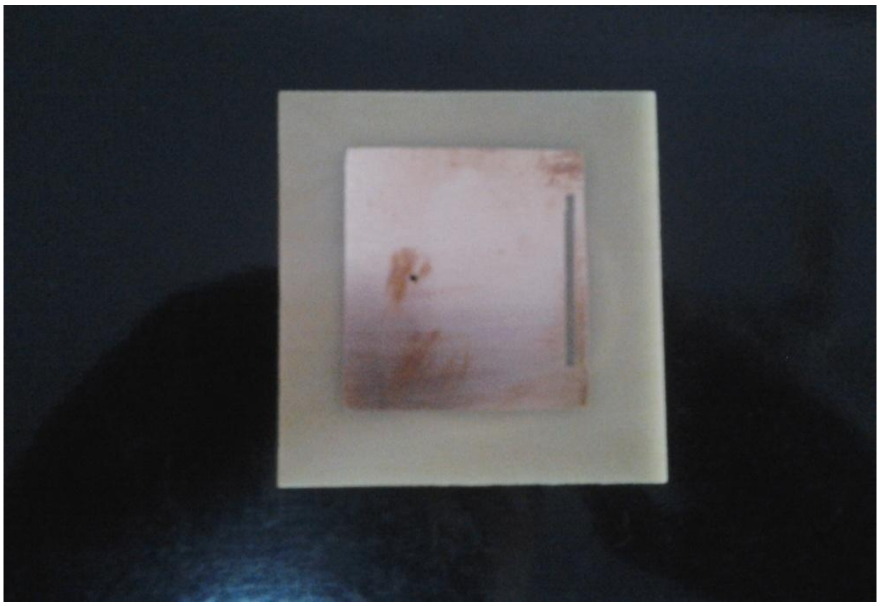


Fig 5.2: Fabricated antenna of coaxial fed dual band microstrip rectangular patch antenna for WLAN application

Fig 5.3: Fabricated antenna of coaxial fed dual band microstrip triangular patch antenna for WLAN application

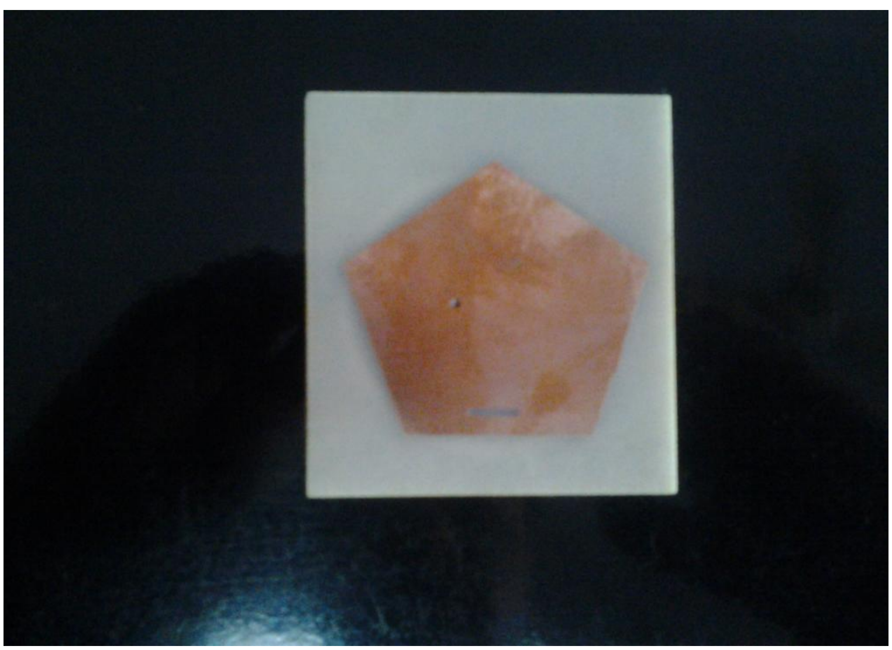


Fig 5.4: Fabricated antenna of coaxial fed dual band microstrip pentagonal patch antenna for WLAN application

5.3 Diagrams of the instruments used while fabricating a microstrip patch antenna:

Fig 5.5: Camera Unit

Fig 5.6: Dip Coating Unit

Fig 5.7: Oven Unit

Fig 5.8: UV Expose Unit

Fig 5.9: PCB Cutter

Fig 5.10: Etching Unit

Chapter 6

Conclusion and Future scope

6.2 Conclusion

In this thesis Microstrip Patch antenna with different shapes for WLAN application has been simulated and fabricated. In this thesis overview of Microstrip antenna has been discussed with advantage and disadvantage of Microstrip Patch Antenna. It can be concluded that Microstrip Patch antenna is advantageous over wire antennas for WLAN devices as requirement of antenna to be conformal.

Further Literature review is presented on different dual band antennas for WLAN applications. In literature review different microstrip antennas are discussed which are published by different authors. It is concluded that lots of research is going on in field of multiband and broad band antenna design. So after literature review objectives were defined to design dual band Microstrip Patch Antenna for WLAN applications.

Design computation and analysis method for Microstrip Patch antenna design is discussed for example transmission line model, cavity model etc. It is inferred that different shapes of patch produces different kind of resonance and different bandwidth. So Microstrip Patch antennas with different shapes of patches are simulated for 2.4 GHz and 5.2 GHz frequencies, which can be used for WLAN applications.

After study of design of different antennas an optimum antenna is considered and simulated which is fabricated at PCB FABRICATION Lab later. It is concluded from the results that return loss of the rectangular and pentagonal patch antennas at both the frequencies 2.4GHz and 5.2GHz are better than that of triangular patch antenna. It is also concluded that dual band pentagonal patch antenna for WLAN applications gives the optimum results at 2.4GHz and 5.2GHz frequencies considering the return loss and the bandwidth simultaneously.

At 2.4GHz the return losses and bandwidths obtained are -19.275dB 91.89MHz, -17.577dB 92.975MHz and-20dB 95.04MHz for rectangular, triangular and pentagonal patch antennas respectively. At 5.2GHz the return losses and bandwidths obtained are -33.711dB 348.34MHz, -23.733 dB 214.36MHz and-28.191dB 325.83MHz for rectangular, triangular and pentagonal patch antennas respectively.

6.2 Future Scope

Although an infinite amount of research has done for optimum antenna designs for wireless applications but still there are many things yet to be done in microstrip antenna. In this thesis, a microstrip patch antenna up to dual band has been presented. Next, one can work out on design the microstrip patch antenna in such a configuration so that we can achieve more than two bands with a sufficient bandwidth. There are various optimization techniques on which one can extend our work to have multiband antenna with sufficient bandwidth i.e. making the antenna broadband. Next, the work on the miniaturization of the microstrip antennas and reduction of mutual coupling between elements in the array can be carried out. One can also extend our work by applying various optimization techniques like

- PSO
- Neural network approach to optimize the design.

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