DESIGN, FABRICATION AND PERFOMANCE AYALYSIS OF SINGLE AND DUAL BAND MSA FOR WLAN & WiMAX APPLICATIONS

A Thesis submitted in partial fulfillment of the

Requirements for the award of the Degree of

MASTER OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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Certificate

I hereby declare that the work which is being presented in the thesis entitled, **"Design, Fabrication And Performance Analysis Of Single & Dual Band MSA For WLAN & WiMAX Applications"** in partial fulfillment of the requirement for the award of degree of Master of Engineering in Electronics and communication submitted in Electronics and Communication Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Ms. Amanpreet Kaur, Assistant Professor, ECED.

The matter presented in this thesis has not been submitted in any other University/Institute for the award of degree.

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It 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. So, there is continuously increasing requirements of efficient and high performance antenna .The features of antenna which every technology requires is light weight, small in size and low cost etc. Apart from this feature antenna also should have wide bandwidth and should have multiple resonant frequencies. Almost all these requirements can be fulfilled by Microstrip patch antenna.

The main aim would be to reduce the number of antennas , this can be done by multibanding and to increase the BW and to present dual band with DGS using aperture feeding technique for WLAN/WIMAX applications. A simple rectangular microstrip patch antenna is designed for a single frequency of 5.2/3.6GHz with aperture and microstrisp line feed feeding techniques. A comparison is made at 5.8GHz with microstrip feed using different patches shapes, in terms of patch size, gain, bandwidth, directivity etc.

Next, various Microstrip antennas for different WLAN/WiMAX and LNB (Low noise Block and transoceanic down converter) application with reduced ground structure and DGS (Defected ground structure) are presented with a dual band. The various parameters like return loss, smith chart, radiation pattern and VSWR etc have been studied and plotted for each simulated antenna. The affects of various parameters like length of the feed, width of the feed and also of slot, and slot location in case of aperture coupling has been presented. Finally, a fabrication procedure has been done and the measured results are compared with simulated ones to validate the antenna performance in practical scenario.

Acknowledgement

To discover, analyze and to present something new is to venture on an untrodden path towards and unexplored destination is an arduous adventure unless one gets a true torchbearer to show the way. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various people. Words are often too less to reveals one's deep regards. I take this opportunity to express my profound sense of gratitude and respect to all those who helped me through the duration of this thesis. I acknowledge with gratitude and humility my indebtedness to **Ms. Amanpreet Kaur, Assistant Professor,** Electronics and Communication Engineering Department, Thapar University, Patiala, under whose guidance I had the privilege to complete this thesis. I wish to express my deep gratitude towards her for providing individual guidance and support throughout the thesis work.

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My greatest thanks are to all who wished me success especially my parents. Above all I render my gratitude to the Almighty who bestowed self-confidence, ability and strength in me to complete this work for not letting me down at the time of crisis and showing me the silver lining in the dark clouds. I do not find enough words with which I can express my feelings of thanks to my dear friends for their help, inspiration and moral support which went a long way in successful competition of the present study.

Manpreet Kaur.

(Manpreet Kaur)

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List of Abbreviations

FCC - Federal communication commission

MMIC- Millimeter -wave integrated circuits

MSA- Microstrip antennas

WLAN- Wireless local area network

IEEE - Institute of Electrical and Electronics Engineers

OFDM- Orthogonal frequency division multiplexing

WiMAX -Worldwide Interoperability for Microwave Access

MICs- Microwave integrated circuits

CPW- Coplanar waveguide

VSWR - Voltage standing wave ratio

BW- Bandwidth

VNA – Vector Network Analyzer

Q - Quality Factor

CST - Computer Simulation Technology

RL – Return Loss

Chapter-1

Introduction

This chapter gives the brief introduction about different wireless standards, wireless communication overview and brief history of wireless communication. This chapter also gives role of antenna, advantages and disadvantages and different feeding techniques. After defining the objective of the seminar report, chapter 1 closes with an outline of the thesis.

1.1 Overview of wireless communication:

Wireless communication demand increases day by day. Today world's communication depends on wireless links, without it, communication in not possible. Cellular systems have experienced exponential growth over the last decade. So, there are around two billion users worldwide. Thus cellular phone has become a critical business for many people to earn money. Wireless networks are more popular today than wired networks, because these are more of cost and difficult to establish. Thus wireless communication is most popular in today's world [1].

The explosive growth of wireless systems coupled with the proliferation of laptops and palmtop computers indicates the bright future of wireless networks.

1.2 Brief history of wireless communication:

The first wireless networks were developed in Pre-industrial age. For these systems information transmitted over line-of-sight distances. Early communication networks were replaced first by telegraph network, which are invented by Samuel Morse in 1838 .In 1895 telephone was invented, Marconi demonstrated the first radio transmission. Then radio technology advanced rapidly to enable transmissions over lager distances with better quality and less power cheap device.

Early radio systems transmitted analog signals. But today's radio system use digital signals for transmission of data in binary form. In 1985 the Federal communication commission (FCC) enables the commercial development of wireless LAN's by authorizing the public use of the industrial, Scientific, and Medical bands for wireless LAN products, but due to poor performance of these products, new generation WLAN were formed.

The current generation of the wireless LAN's based on family IEEE 802.11 standards have better performance, but still low data rates. These are providing few applications such as e-mail and web browsing that are not sufficient applications today's users. For many applications we need wide band and wide band are formed by using many designing techniques. Different types of antennas are used to get wide band for many applications. The generations 1G, 2G, 3G and 4G for wireless communication with brief view are:

1.2.1The First Generation:

It can also be a good choice for long range communication. The technology used here (AMPS) which is 2G standard using frequencies at 800MHz. It could accommodate 5 to 10 times more users than IMTS by dividing an area into smaller cells hence the term ‘cellular network’ came into existence. The first generation (1G) analog cellular systems supported voice communication with limited roaming E.g. AMPS.

1.2.2 The Second Generation

Second Generation (2G) wireless cellular services was a step ahead of First Generation(1G) services by providing the facility of short message service(SMS) unlike 1G that had its prime focus on verbal communication. A typical 2G G.S.M network service ranges from 800/900MHz or 1800/1900 spectrum. The bandwidth of 2G is 30-200KHz. Eg. GSM, GPRS.

1.2.3 The Third Generation

In 3G, Wide Brand Wireless Network is used with which the clarity increases and gives the perfection as like that of a real conversation. The data are sent through the technology called Packet Switching .Voice calls are interpreted through Circuit Switching. It is a highly sophisticated form of communication that has come up in the last decade. In addition to verbal communication it includes data services, access to television/video, categorizing it into triple play service. 3G operates at a range of 2100MHz and has a bandwidth of 15-20MHz. High speed internet service, video chatting are the assets of 3G. e.g. CDMA

1.2.4 The Fourth Generation of Mobile Wireless Communication System

A successor of 2G and 3G, 4G promises a downloading speed of 100Mbps and is yet to shower its wonders on. then with the case of Fourth Generation that is 4G in addition to that of the services of 3G some additional features such as Multi-Media Newspapers, also to watch T.V programs with the clarity as to that of an ordinary T.V. In addition, we can send Data much faster that of the previous generations. It is expected to provide a comprehensive and secure all IP based solutions.

1.3 Wi-MAX and WLAN – Latest Technology

Wi-Fi is based on IEEE 802.11 standard whereas WiMAX is based on IEEE 802.16. However both are IEEE standards. Wi-Fi typically provides local network access for around a few hundred feet with speeds of up to 54 Mbps, a single WiMAX antenna is expected to have a range of up to 40 miles with speeds of 70 Mbps or more. As such, WiMAX can bring the underlying Internet connection needed to service local Wi-Fi networks.

Table 1.1: Comparison between WiMAX and Wi-Fi

Feature	WiMax (802.16a)	Wi-Fi (802.11b)	Wi-Fi (802.11a/g)
Primary Application	Broadband Wireless Access	Wireless LAN	Wireless LAN
Frequency Band	Licensed/Unlicensed 2 G to 11 GHz	2.4 GHz ISM	2.4 GHz ISM (g) 5 GHz U-NII (a)
Channel Bandwidth	Adjustable 1.25 M to 20 MHz	25 MHz	20 MHz

Half/Full Duplex	Full	Half	Half
Radio Technology	OFDM (256-channels)	Direct Sequence Spread Spectrum	OFDM (64-channels)
Bandwidth Efficiency	<=5 bps/Hz	<=0.44 bps/Hz	<=2.7 bps/Hz
Modulation	BPSK, QPSK, 16-, 64-, 256-QAM	QPSK	BPSK, QPSK, 16-, 64-QAM
Access Protocol	Request/Grant	CSMA/CA	CSMA/CA

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. Broad banding is the main problem, for solving this problem there are many broad-banding techniques available.

- Bandwidth can also be enhanced by using parasitic patches [2]
- By using stacking [3]
- By using U-slot within the patch [4]
- Microstrip patch, with inserted slits at one of the radiating edges [5] etc.

1.4 Role of an Antenna:

Antennas transfer energy from a cable into the air waves efficiently. Any transmit antenna can also be a receive antenna and vice-versa. If you wish to transmit high power from an antenna, usually heat generation or high voltage is a concern that can destroy the antenna. To prevent problems, high power antennas require thicker wires and sometimes insulators to prevent overheating/burning and arcing. Many antennas can simply be made of wire of a simple length and they'll be very efficient. The length of an antenna changes its efficiency to the cable. If you want the antenna to be efficient, you must size it to match the cable impedance. Receiver antennas are often made smaller than either transmit or transceiver antennas. Thus for wireless communication an antenna plays main role for communication at larger distances. Also Microstrip patch antenna mostly required for large coverage and wireless applications.

1.4.1 Basic Microstrip Patch Antenna:

In its most fundamental form, a Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1.1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. A microstrip patch antenna consists of the following:

- ❖ A radiating patch (perfect electric conductor)
- ❖ Substrate (mainly FR4)
- ❖ Ground (perfect electric conductor

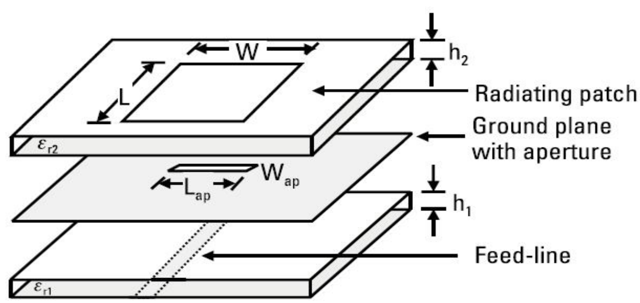


Figure 1.1: Structure of microstrip patch antenna

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in Figure 1.2. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

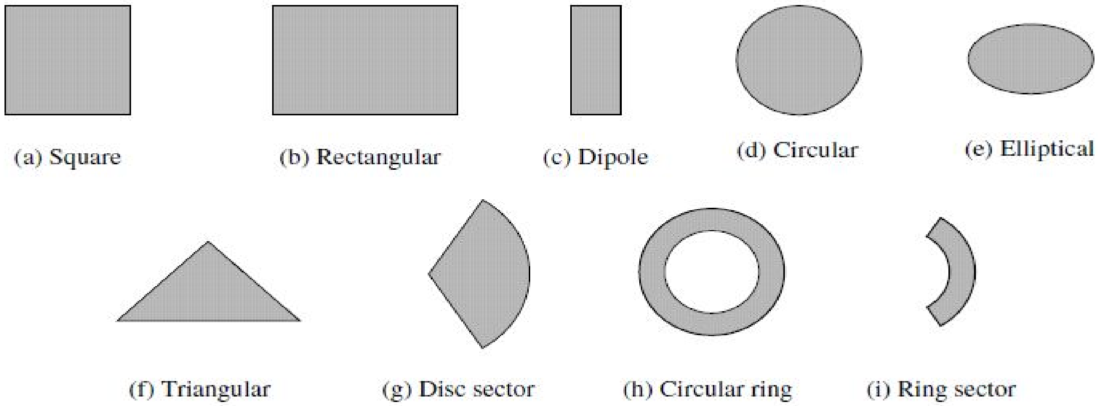


Figure 1.2: Common shapes of microstrip patch elements

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance [6].

1.5 Microstrip Patch Antenna as the Optimum Choice:

In telecommunication, there are several types of microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or patch antenna. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a PCB (printed circuit board), with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead made of a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but has a wider BW. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.

The most commonly employed microstrip antenna is a rectangular patch. The rectangular patch antenna is approximately a one-half wavelength long section of rectangular microstrip transmission line. When air is the antenna substrate, the length of the rectangular microstrip antenna is approximately one-half of a free-space wavelength.

1.6 Advantages and Disadvantages

Some of their advantage discussed are given below [6]:

• 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.

• Supports both, linear as well as circular polarization.

• Can be easily integrated with microwave integrated circuits (MICs).

• Capable of dual and triple frequency operations.

• Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from more drawbacks as compared to conventional antennas. Some of their major disadvantages are given below:

• Narrow bandwidth

• Low efficiency

• Low Gain

• Extraneous radiation from feeds and junctions

• Poor end fire radiator except tapered slot antennas

• Low power handling capacity.

• Surface wave excitation

1.7 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 fusing
- ❖ Missile and telemetry

1.8 Models of Analysis:

The preferred models for the analysis of Microstrip patch antennas 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. The cavity model is more accurate and gives good physical insight but is complex in nature.

1.8.1 Transmission-Line Model

Basically the transmission-line model represents the microstrip antenna by two slots, separated by a low-impedance Z_c transmission line of length L

(A) Fringing Effects

Because the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing. This is illustrated along the length in Figures 3.1(a,b) for the two radiating slots of the microstrip antenna. The same applies along the width. The amount of fringing is a function of the dimensions of the patch and the height of the substrate. For the principal E-plane (xy-plane) fringing is a function of the ratio of the length of the patch L to the height h of the substrate (L/h) and the dielectric constant of the substrate. Since for microstrip antennas L/ h >>1, fringing is reduced; however, it must be taken into account because it influences the resonant frequency of the antenna.

The same applies for the width. Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ε_{ref} is introduced to account for fringing and the wave propagation in the line.

For a line with air above the substrate, the effective dielectric constant has values in the range of $1<<\varepsilon_{reff}<\varepsilon_{r.}$ For most applications where the dielectric constant of the substrate is much greater than unity ($\varepsilon_r >>1$), the value of will be closer to the value of the actual dielectric constant of the substrate. The effective dielectric constant is also a function of frequency.

As the frequency of operation increases, most of the electric field lines concentrate in the substrate. Therefore the microstrip line behaves more like a homogeneous line of one dielectric (only the substrate), and the effective dielectric constant approaches the value of the dielectric constant of the substrate [39].

The effective dielectric value of the substrate is given by:

$$W/h > 1$$

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \qquad 1.1$$

(B) Effective Length, Resonant Frequency, and Effective Width

Because of the fringing effects, electrically the patch of the microstrip antenna looks greater than its physical dimensions. For the principal E-plane (xy-plane), this is demonstrated in Figure 1.3 where the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is a function of the effective dielectric constant and the width-to-height ratio (W/h).

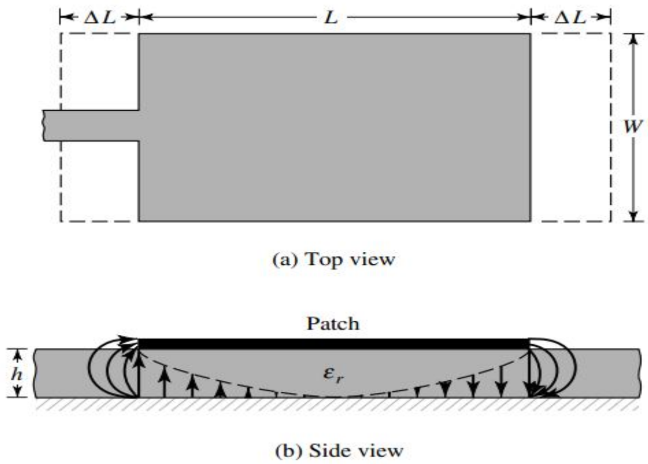


Figure 1.3: Physical and effective length of microstrip patch antenna

A very popular and practical approximate relation for the normalized extension of the length is

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon reff + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon reff - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad 1.2$$

Since the length of the patch has been extended by ΔL on each side, the effective length of the patch is now (L=λ/2 for dominant TM_{010} mode with no fringing)

$$L_{eff} = L + 2\Delta L \qquad 1.3$$

For the dominant TM_{010} mode, the resonant frequency of the microstrip antenna is the function of length. Usually it is given by:

$$(f_r)_{010} = \frac{1}{2L\sqrt{(\varepsilon r)}\sqrt{\mu o \varepsilon o}} = \frac{Vo}{2L\sqrt{(\varepsilon r)}} \qquad 1.4$$

Where v_0 is the speed of the light in free space [40].

(C) Design

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

Frequency of operation (F_r): Figure 1.4 shows the Aperture Coupled Microstrip Patch Antenna. The resonant frequency of the antenna must be selected appropriately. The antenna designed should be useful for the S-band and C-band communication system. The frequency range of S and C-band is approximately 2 to 8GHz. The resonant frequency selected for my design is 5.2/3.6GHz [41].

Dielectric constant of the substrate (ε_r): The dielectric constant of substrate (ε_r) 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.

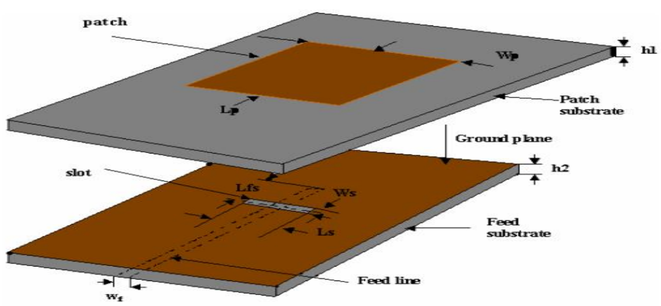


Figure 1.4: Aperture Coupled Microstrip Patch Antenna (Exploded View) [41]

Height of dielectric substrate (h): For the Microstrip patch antenna to be used in 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 mathematically.

Step 1: Calculation of Width (W)

For an efficient radiator, practical width that leads to good radiation efficiencies is [40].

$$\mathbf{W} = \frac{1}{2fr\sqrt{(\mu o\varepsilon o)}}\sqrt{\frac{2}{\varepsilon r+1}} \qquad \text{where } V_0 \text{ is the velocity of light} \qquad 1.5$$

Step 2: Calculation of Effective Dielectric Coefficient (ε_r):

The effective dielectric constant is given by:

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+12\frac{h}{W}]^{-1/2} \quad 1.6$$

Step 3: Calculation of Effective Length (L_{eff}):

The effective length is given by,(the value of "c" is known)

$$L_{eff} = \frac{c}{2fo\sqrt{(\varepsilon reff)}} \quad 1.7$$

Step 4: Calculation of Length Extension (L)

Before calculation of "L", ΔL will be calculated by

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon reff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{W}{h}+0.8)} \quad 1.8$$

Step 5: Calculation of actual Length of Patch (L):

Thus, the actual length of radiating patch is obtained by

$$L = L_{eff} - 2\,\Delta L \quad 1.9$$

Step 6: Calculation of Ground Dimensions (L_g, W_g)

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown by [19] that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery [42]. Hence, for this design, the ground plane dimensions would be given as:

$$L_g = 6h + L \text{ and } W_g = 6h + W \quad 1.10$$

1.8.2 Antenna Parameters

It is important to discuss the parameters in details that are to be analyzed in simulation to design MSA at any frequency. The basic parameters given below discussed in detail according to their impotence.

1. Return Loss: It is the difference between forward and reflected power, represented in dB, generally measured at the input to the coaxial cable connected to the antenna. Let, the power transmitted by the source antenna is P_t and the power reflected back is P_r, then the return loss is given by $P_{r.}$ For maximum power transfer the return loss should be as small as possible means should be more negative because, the return loss is the negative of the reflection coefficient expressed in decibels. Thus we measure return loss at -10dB. This means that the ratio P_r/P_t should be as small as possible in negative range.

2. Smith Chart: It was invented by Phillip H. Smith (1905-1987), is a graphical aid or nomogram specializing in radio frequency (RF) engineering to assist in solving problems with transmission lines and matching circuits. Normalized scaling allows the Smith Chart to be used for problems involving any characteristic impedance or system impedance, although by far the most commonly used is 50 ohms.

3. Bandwidth: It is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." The bandwidth can be considered to be the range of frequencies, on either side of a center frequency (usually the resonance frequency for a dipole), where the antenna characteristics (such as input impedance, pattern, beam-width, polarization, side lobe level, gain, beam direction, radiation efficiency) are within an acceptable value of those at the center frequency.

4. VSWR: When a transmission line (cable) is terminated by an impedance that does not match the characteristic impedance of the transmission line, not all of the power is absorbed by the termination. Part of the power is reflected back down the transmission line. The forward (or incident) signal mixes with the reverse (or reflected) signal to cause a voltage standing wave pattern on the transmission line. The ratio of the maximum to minimum voltage is known as VSWR, or Voltage Standing Wave Ratio. A VSWR of 1:1

means that there is no power being reflected back to the source. This is an ideal situation that rarely, if ever, is seen. In the real world, a VSWR of 1.2:1 (or simply 1.2) is considered excellent in most cases. At a VSWR of 2.0, approximately 10% of the power is reflected back to the source. Not only does a high VSWR mean that power is being wasted, the reflected power can cause problems such as heating cables or causing amplifiers to fold-back.

4. Gain: It is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna is radiated isotropic ally. The radiation intensity corresponding to the isotropically radiated power is equal to power accepted (input) by the antenna divided by 4π.when the direction is not stated, the power gain is usually taken in the direction of maximum radiation.[3]

It is given as:

$$\textbf{Gain} = 4\pi\frac{radiation\ intensity}{total\ input\ (accepted)\ power} \tag{1.11}$$

5. Directivity: It is defined as the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged over all the directions. The average radiation intensity is equal to the total power radiated by the antenna divided 4π. If the direction is not specified, the direction of maximum radiation intensity is implied. The directivity of the non-isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source. In numerical form, directivity is given by:[3]

$$\mathbf{D = U/U_0 = 4\pi U_{max}/\ P_{rad}} \tag{1.12}$$

Where U=radiation intensity (W/unit solid angle)

U_o = radiation intensity of an isotropic antenna (W/unit solid angle)

U_{max} = Maximum radiation intensity (W/unit solid angle)

P_{rad} = total power radiated (W)

6. Beam width: It is defined as the angular separation between two identical points on opposite side of the pattern maximum.

7. Efficiency: It is used to take into account losses at the input terminals and within the structure of the antenna. Such losses may be due, to

1. Reflections because of the mismatch between the transmission line and the antenna

2. I^2R losses (conduction and dielectric)

1.9 Feed Techniques:

One of the important aspects of microstrip patch antenna is the variety of feeding technique applicable to them. 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)
- Coaxial probe (contacting schemes)
- Aperture coupling (non-contacting schemes)
- Proximity coupling (non-contacting schemes)
- Coplanar waveguide feed (contacting schemes)

1.9.1 Microstrip Line Feed:

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Figure 1.5.

The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

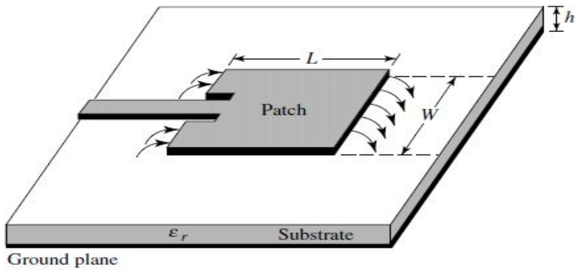


Figure1.5: Microstrip Line Feed

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.

1.9.2 Coaxial Feed:

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas.

As seen from Figure1.6, 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.

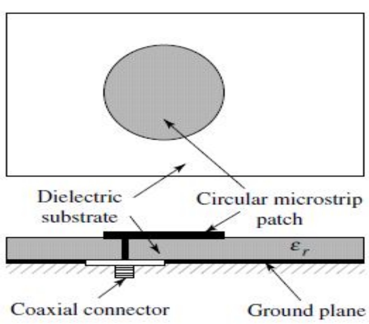


Figure 1.6: Probe fed Rectangular Microstrip Patch Antenna

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 radiati

1.9.3 Aperture Coupled Feed:

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 1.7. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

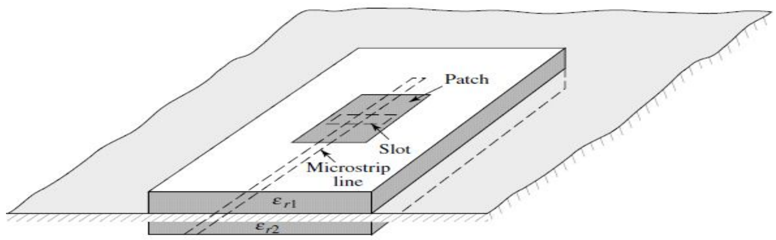


Figure 1.7: Aperture-coupled feed

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. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness.

1.9.4 Proximity coupled feed:

This type of feed 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 1.8, 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.

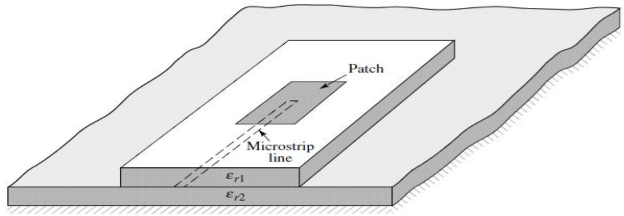


Figure 1.8: Proximity-coupled feed

1.9.5 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. basic diagram is shown in figure 1.8.

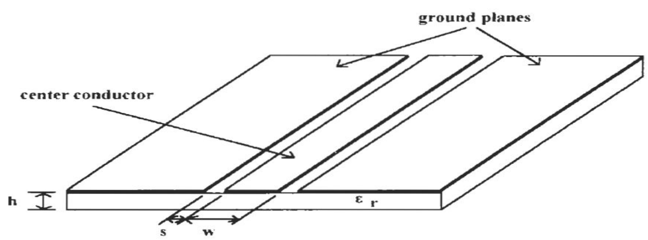


Figure1.8: Coplanar Waveguide feed

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 1.9(a) the center conductor of the CPW divides the coupling slot into two. The CPW is transformed into a slot of length Ls in figure 1.9(b). The coupling between CPW and patch is inductive in figure 1.9(a) while is capacitive in figure 1.9(b).

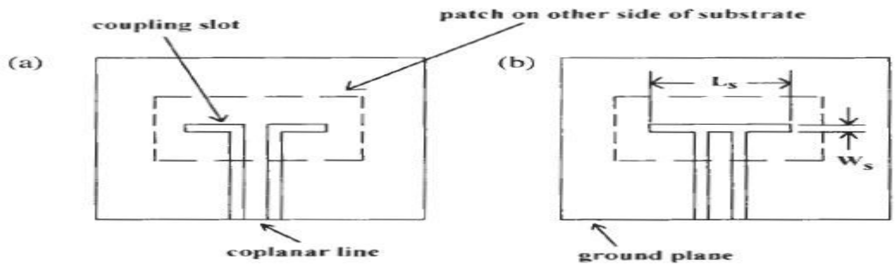


Figure1.9: Coplanar Waveguide fed antennas: (a) inductive (b) capacitive coupling

1.10 Objective of Report:

- Objective of the Report to design a rectangular microstrip patch antenna for a single frequency with aperture feeding technique and microstrip line feed to form wideband for WLAN/WIMAX applications, and dual-band antenna with reduced ground for WLAN.
- This Thesis report also gives the overview of wireless communication and study of Microstrip Patch Antenna.
- A comparative study, design and fabrication of a microstrip patch antenna bands using aperture and microstrip line feeding techniques for different WLAN (Wireless Local Area Network) and WIMAX (Worldwide Interoperability for Microwave Access) bands.

1.11 Outline of the Thesis

The thesis is composed of 7 chapters and organized as follow:

Chapter 1:- Concentrates on the brief overview of the microstrip patch antenna, Role of antenna and history for wireless communication and study on 1G, 2G, 3G and 4G and different feeding techniques, advantages and disadvantages.

Chapter 2:- History and reviews of the microstrip patch antenna and provides a literature review related to the designing of the microstrip patch antenna with aperture, microstrip line feeding techniques and also with defected ground structures.

Chapter 3:- Results of Microstrip Patch Antenna using aperture feed and microstrip-line feed for single band and discussion through gain, directivity, return loss, different fields etc. This chapter also discuss the comparison using different shaped patches with microstrip line feed.

Chapter 4:- Provides the design and development of a microstrip patch antenna with aperture coupling and microstrip line feed. The parameters like return loss, smith chart, radiation pattern and VSWR etc. are plotted and studied for each antenna.

Chapter 5:- Results of Microstrip Patch Antenna using aperture feed for dual-band (with reduced ground structure and DGS) and Dual band antenna with DGS using microstrip line feed, discussion through gain ,directivity, Return loss, different fields etc.

Chapter 6:- Presents the fabrication process of a microstrip patch antenna using aperture feed.

Chapter 7:- Concludes the work carried out in this thesis with the future scope and future Prospective of the microstrip patch antenna.

Chapter 2
Literature Survey

This chapter concentrates on the literature review of the microstrip patch antenna. By studying the data through many sources we work for future for improving the performance of microstrip patch antenna by simulation method. This chapter includes literature review on aperture feed, microstrip line feed and more done on MSA with DGS.

2.1 Literature survey for aperture and microstrip line feed:

The concept of microstrip antenna was first proposed by Deschamps in 1953. A patent was issued in France in 1955 in the names of Gutton and Baissinor. After the 1970s research publications started to flow with the appearance of the first design equation. Since then different authors started investigation on microstrip patch antennas like James hall, David M. Pozar and there are also some contributed a lot. Throughout the years, authors have dedicated their investigations to create new designs or variations to the original antenna that, to some extent; produce either wider bandwidth or multiple frequency operation in a single element.

2.2 Progress of the Aperture coupled Microstrip Antenna

"A Review of Aperture Coupled Microstrip Antennas", History, Operation, Development, and Applications is done in 1996 by "David M. Pozar". He gives sufficient information about Microstrip patch antenna using aperture feed [7]. There are number of methods are used to enhance BW, Dual or multi-band antennas. The DGS can also be used to improve the performance of the antenna.

2.2.1 Bandwidth enhancement in Aperture coupled microstrip antennas

One of the useful features of the microstrip antenna is that it can provide substantially improved impedance bandwidths due to the additional degrees of freedom by stub length and coupling aperture size. A high-performance, 16-element planar array antenna has been constructed using a global concept which optimizes both the electrical and the mechanical characteristics and includes a radome. It has high-gain, very wide bandwidth for a printed antenna, strong mechanical characteristics, very low weight, and low price. Two variations of a novel feeding technique for a wideband circularly polarized aperture-coupled microstrip antenna. The feasibility of printed antennas which meet all the criteria for satellite communications antennas. These criteria are a bandwidth greater than 20 percent for a VSWR of less than 1.5, cross polar level lower than -30 dB over 20-deg solid angle, and gain better than 8 dB throughout the bandwidth. While single layer probe or microstrip line–fed elements are typically limited to Bandwidths of 2%-5%, but aperture coupled antennas provide up to 10%-15% bandwidths with single layer [8], [9], [10] , An aperture-coupled microstrip stacked patch antenna is studied with the goal of obtaining wide bandwidth, low cross-polarization, and weak parasitic radiation from the feeding aperture for applications in printed phased array antennas and K-band aperture-coupled stacked microstrip antennas are studied and The effects of varying physical parameters of the structure are investigated with the goal of designing millimeter-wave wideband microstrip antennas. Bandwidths in excess of 20 percent are obtained and up to 30-50% bandwidth formed using stacked patch configuration [11], [12], [13], [14].

Antenna coupled antenna with an H-shaped aperture are presented. The presented antenna has a wide bandwidth, high gain, and low cross-polarization levels with only one-patch. The measured bandwidth of this antenna is 56.2%. The maximum gain at 2.05 GHz is 10.4 dBi and the 3 dB gain bandwidth with a center frequency at 2.17 GHz is 24%. Thus bandwidth can be enhanced by using H-shaped [15]. |Bandwidth enhancement technique of circularly polarized square slot antenna is presented in this paper. A square slot antenna with the components of L-probe separated could achieve an axial ratio (AR) bandwidth of 33.84%. Creating an L-shaped slot on the ground plane, where the electric field rotates in the desired clockwise direction, can further enhance the bandwidth by 7% [16], In this paper a multifunctional microstrip antenna is designed, fabricated and experimentally verified for operation in AWS, GSM, WiMAX and WLAN bands. This microstrip patch antenna has two U-shaped slots to achieve the dual wideband operation required to meet these specifications [17].

A new technique to increase the bandwidth of slot antenna without increasing the volume of the antenna is obtained by using Z-slot and splitting the two side of the Z- slot into two or three fingers is proposed by C.-J. Wang and S.-W. Chang. According to the results, the proposed triple-slot antenna can provide two separated impedance bandwidths of 672 Hz (about 28.3% centered at 2.4 GHz band) and 2752 MHz (about 53.5% centered at 5.2 GHz band), making it easily cover the required bandwidths for WLAN operation in the 2.4 GHz band and 5.2/5.8 GHz bands [18].

2.2.2 Dual Frequency Aperture Coupled Microstrip Antennas

An overview about the dual-frequency techniques for patch antennas, Orthogonal-mode dual- frequency patch antennas, Multi-patch dual-frequency antennas, Reactively loaded patch antennas, geometries for single and dual linear polarization, slotted rectangular-patch antenna, slotted cross-patch antenna, Cross-sub-array dual-frequency patch antenna is discussed by S. Maci and G. Bifji Gentili [19].

An annular ring has also been for dual frequency where the frequency for the propagation modes can be adjusted by choosing the inner and the outer radii. However, the ratio of two frequencies is somewhat limited [20]. It is also possible to achieve dual frequency operation of a patch antenna by loading slots at both the resonating side and at the non-resonating side of the patch and by using shorting pins. A novel dual-frequency rectangular microstrip antenna with a pair of step-slots embedded close to the non-radiating edges is proposed and experimentally studied. The two operating frequencies have the same polarization planes and similar broadside radiation characteristics. By adjusting the step ratio of the step-slots, the frequency ratio of the two operating frequencies is tunable in the range -1.23-1.63 [21, 22].

2.2.3 Antenna for WLAN and other Wireless Applications

A single fed aperture coupled antenna for WLAN application is designed and discussed by Rashid A. Saeed, S. Khatun, Borhanuddin, M. A. Khazani, Raina A. Mokhtar and Mahmoud Alshamary [23]. A dual-band antenna covering both the bands (2.25 and 5.2GHz) for WLAN Application is designed by combining a rectangular and two “L” shaped radiating element embedding them on a single layer structure and achieved

bandwidth of 30% and 20% while maintaining the structural compact size [24].
Multi-frequency antenna for various wireless applications is designed by using manifold slot structures like the printed slot, the slotted form and inverted- L slot [25].
“The Study of Aperture-coupled Dual-band Microstrip Patch Antennas”, this paper presents aperture-coupled dual-band microstrip antenna for application in WiMAX and WLAN systems is presented. The dual-band antenna operates in 2.4 GHz and 3.6 GHz. It is composed of two radio patches and a feeding network, aperture-coupled technology and stacked technology [26].

2.3 Progress of the Microstrip Line Feed Antenna

Microstrip line feeding technique also attracted researchers because of several advantages over other feeding techniques. In this feed technique, the feed line and patches can be etched on one board, thus, it makes fabrication easy and the input impedance is easily controllable. Microstrip line patches have bandwidth and gain characteristics which are relatively narrow. This technique also suffers from poor surface wave efficiency and relatively high spurious feed radiation. Different shaped-patches can be used for making single band antenna [6, 27].
In 2003 Y. L Kuo, K. –L Wong proposed an antenna that was designed for dual band operation “Printed Double T-Monopole antenna for 2.4/5.2 GHz Dual-band WLAN Operations. It is a microstrip-fed double-T monopole antenna, comprises two stacked T-shaped monopoles of different sizes, which generate two resonant modes for desired dual band operations, and covers 2.4 and 5.2 GHz bands at 50ohm impedance for WLAN operations [28].

Recently in 2009, Mohammed Al-Husseini et al. [29] presented a low-cost ultra-wide band microstrip antenna for wireless communications used for 3G/WLAN/WiMAX and UWB Applications. The ground plane is partial and comprises a rectangular part and a trapezoidal part. The patch is a half ellipse, where the cut is made along the minor axis. Several slots are incorporated into the patch.

In 2010, Kuang Fuqiang et al. [30] presented a triple band antenna named “A triple-band

Microstrip Antenna for WLAN Applications". The proposed antenna is made up of two one-quarter wavelength resonating components, fed by a 50ohmic microstrip line. The lower and higher resonant frequencies can be easily tuned by adjusting a few parameters of the presented antenna.

2.4 Progress in the Field of increasing BW using DGS:

Wen-Chung Liu et al. [31] presents triple band antenna in 2011, "Design of Triple Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure". Defected ground structure (DGS) is used in this antenna, which has a rectangular patch with dual inverted L-shaped strips and is fed by a cross-shaped strip-line, operates over the frequency ranges, 2.14–2.52 GHz, 2.82–3.74 GHz, and 5.15–6.02 GHz suitable for WLAN 2.4/5.2/5.8 GHz and WiMAX 3.5/5.5 GHz applications.

In this paper, rectangular microstrip patch antenna (RMPA) uses with height 1.6mm and the dielectric constant is 4.4 is used. The half circular slot etched on the patch at the top right as DMS, two circular slots etched on the ground plane as DGS. Thus, the bandwidth of 230MHz (the average gain of 4.65dBi) with respect to center frequency 5.23GHz which High Performance Local Area Network type 1 (HIPERLAN/1) [32].
Rajeshwar Lal Dua, Himanshu Singh, Neha Gambhir in 2012 using DGS presents, " 2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth" The proposed antenna has been simulated at 2.45 GHz frequency. This compact antenna fed by Quarter Transformer feeding. This type of feeding is mostly used for impedance matching purposes. The antenna is simulated by the software HFSS [33].
The proposed antenna structure in this paper can be used for IMT-E (UMTS) and Wi-MAX, can also be used for S-Band and C-Band applications. This is multi-band antenna. Substrate thickness h=1.6mm and dielectric constant of 4.4(FR-4) is used [34].

2.5 Research Gaps

- As the variations in antenna thickness yield improved results in terms of return loss but we can use dielectric substrates with different permittivity's. Since the upper substrate in aperture coupled antenna prefers low permittivity and lower substrate prefers high permittivity for appropriate functionality, the asymmetric variations in dielectric constant of the whole antenna body need to be worked up on to bring out more distinctive and improved results.

- Two different slot configurations proposed are transverse slot and longitudinal slot. Although the first configuration is simpler and does not need impedance matching as compared to the second one, the longitudinal slot antenna provides wider bandwidth [26]. The defected ground structures can be used in the longitudinal slot configurations to improve the bandwidth and increase the gain.
- The use of parasitic elements, stacked patches, using thick substrates of low permittivity etc have proved to improve the bandwidth of the antenna [20] However, the broad banding design in microstrip antenna results in high volume in spite of its efficient results. The work regarding the reduction of the profile can be done.
- A novel structure called DGS & Defected microstrip structure are used to reduce the size of patch antennas without degrading the performance of antenna.
- The use of different shaped patch antenna geometry has brought good performance in the VSWR and in response at low dielectric constant. Work can be done to analyze the antenna by taking the slot shape exactly as the patch shape.
- Different shaped slots on ground can help in achieving multiband applications. As different parameters of the slots are varied to get single, dual and quad band antennas.
- The air gap in microstrip patch antenna also plays an important role. With the variation in the air gap, multiple bands can be achieved.
- With the defected ground structure having different shapes can be used to reduce the higher order modes obtained also increase the bandwidth and increase the gain.
- The effects of dielectric position on top layer, changing the positions of patches horizontally, length and position of the slot, and the length of the top patch can provide high coupling and also increase the gain and bandwidth.

Conclusion

In this chapter, the literature survey for aperture coupling and microstrip line feeding techniques has been studied.

Chapter 3

Design of Single Band Antennas for Wireless Application

In this chapter, a microstrip patch antenna is designed with aperture and microstrip line feeding techniques for WLAN application at a single frequency of 5.2GHz/3.6GHz and a comparison is made between various parameters like bandwidth, patch size, gain, radiation efficiency, VSWR and directivity at 5.8GHz using microstrip line feed. The return loss, radiation pattern, VSWR and smith chart have also been studied.

3.1 Design of Rectangular Microstrip Patch Antenna

The rectangular patch antenna is approximately a one-half wavelength long section of rectangular Microstrip transmission line. When air is the antenna substrate, the length of the rectangular Microstrip antenna is approximately one-half of a free-space wavelength. The length of the antenna decreases as the relative dielectric constant of the substrate increases. The resonant length of the antenna is slightly shorter because of the extended electric "fringing fields" which increases the electrical length of the antenna slightly [6].

A single element of rectangular patch antenna, can be designed for 5.8/3.6 GHz resonant frequency using transmission line model .

3.2 Design of Microstrip Antenna at 5.2GHz:

The geometry of proposed antenna which is aperture fed for WLAN applications is depicted in figure 3.1. The radiating patch and the microstrip feed line are separated by the ground plane Coupling between the patch and the feed line is made through a slot or an aperture cut in the ground plane.

This feeding technique provides largest bandwidth. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers. The main dimensions of design are given in below Table3.1.

Table 3.1 Dimension of the designed antenna with aperture feed:

Substrate Material	FR4
Substrate Height	1.570mm
Substrate Size	22.64x26.96mm
Dielectric Constant	4.4
Ground Size	22.64x26.96mm
Patch Size	11.058x17.4mm

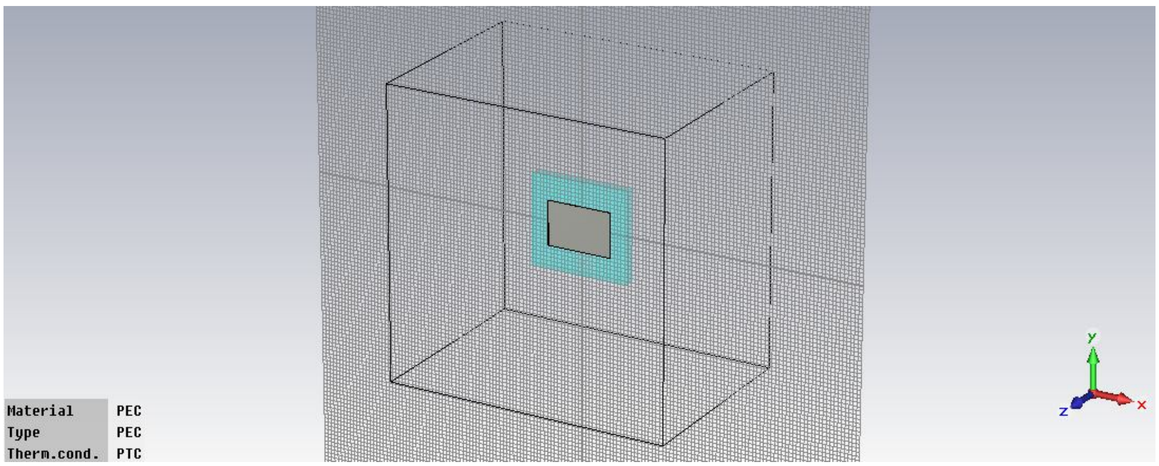


Figure 3.1: Geometry dimension of proposed antenna at 5.2GHz (aperture feed)

This is diagram given using CST2010 for aperture coupled antenna. The design relating parameters study is discussed one by one below. Brief idea about these parameters is given as:

3.2.1 Return Loss and BW:

The return loss should be more negative for best power coupling, as per discussed antenna parameters (equation1.11) in chapter1 for better performance and wideband requirement. That is, return loss is the negative of the reflection coefficient expressed in decibels. Thus we measure return loss at -10dB. The return loss plot for the designed antenna with aperture feed is -32.44dB shown in figure 3.2 as below. The bandwidth of the antenna can be said to be those range of frequencies over which the return loss is greater than -10 dB (corresponds to a VSWR of 2). Thus, 10dB bandwidth is about 285MHz (5.335-5.0498GHz).

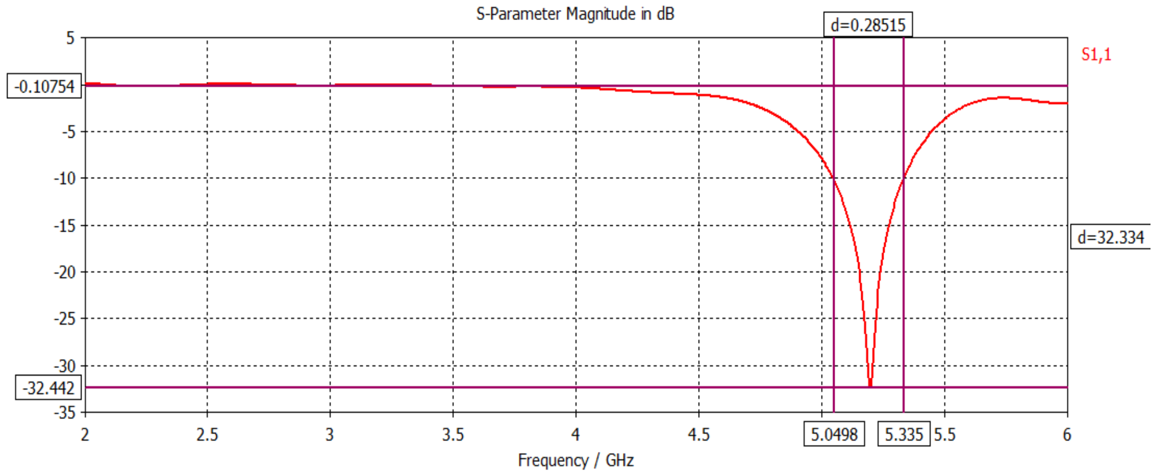


Figure 3.2: Simulated return loss [S11] at 5.2GHz

3.2.2 Smith Chart:

Figure 3.3 shows the smith chart results at 50ohm impedance. The smith chart represents that how antenna impedance varies with frequency. Thus from figure circle cuts the resistive part at 0.78 and after normalization the results is at 50ohm, result is formed 50 ohm. For proper matching the locus must be large enough that it passes through the center of the smith chart.

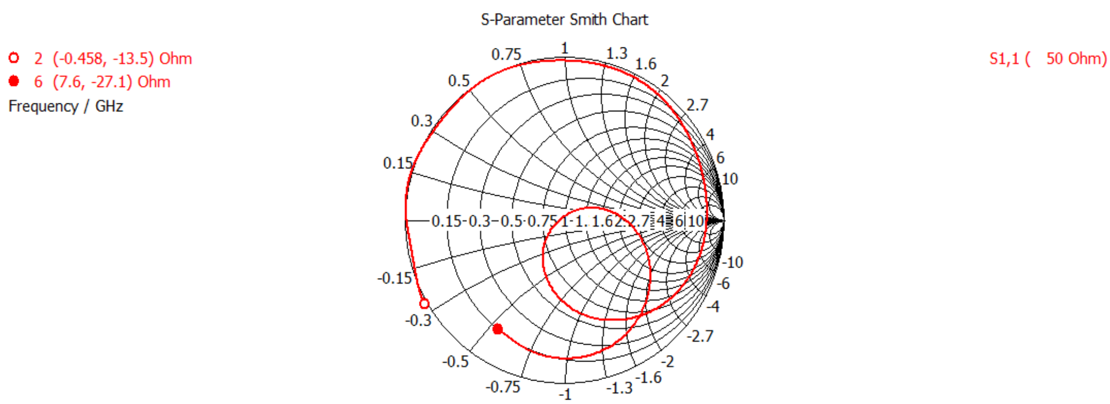


Figure 3.3: Smith chart [S11] at 5.2GHz

3.2.3 Radiation Pattern:

Figure3.4 and figure3.7 shows the radiation pattern and polar-plot for the proposed antenna with 6.003dB gain at 5.2GHz frequency. The gain of the antenna in a particular direction is more as compared to isotropic antenna radiating in all directions which is very useful for WLAN applications for providing a better performance

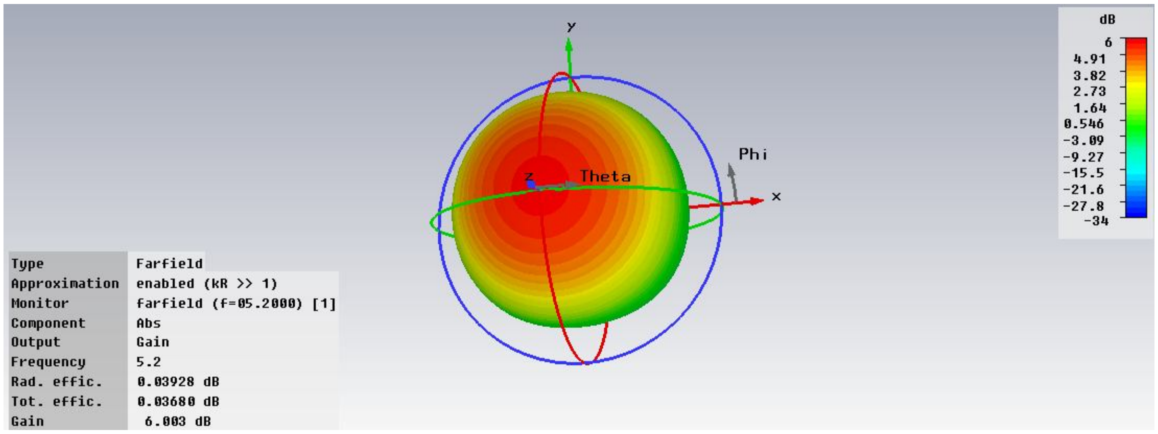


Figure 3.4: 3D Radiation pattern plot at 5.2GHz

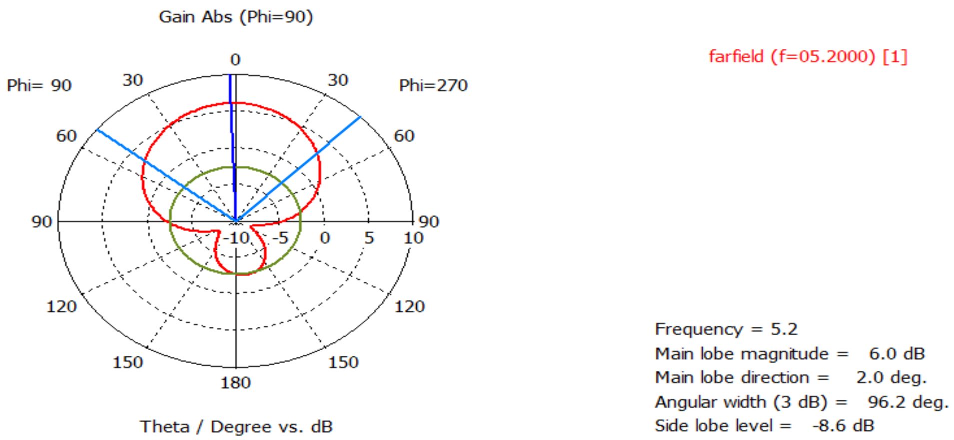


Figure 3.7: Polar-plot of Gain at 5.2GHz

It can be seen that at a frequency of 5.2GHz, gain is 6.003dB, radiation pattern obtained is Omni-directional with main lobe directed at an angle of 2.0 degree, having angular beam width of 96.2 degree. The magnitude of the main lobe is 6.0dB.

3.3.3 Directivity: The Directivity plot as shown in figure 3.5 represents amount of radiation intensity i.e. is equal to 5.964dBi. The antenna radiates more in a particular direction as shown in polar plot, as compared to the isotropic antenna which radiates equally in all directions, by an amount of 5.964dBi.

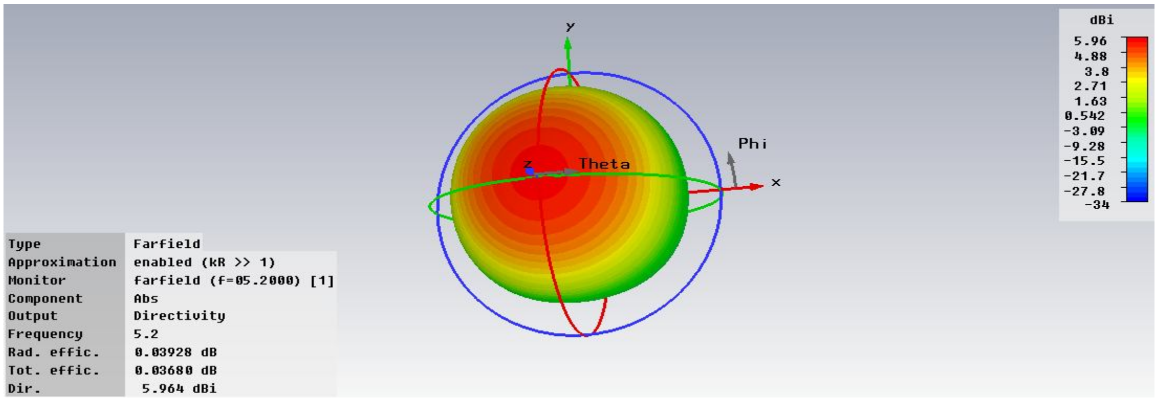


Figure 3.5: 3D-directivity plot at 5.2GHz

The directivity 5.964dBi at 5.2GHz for far-field and the radiation efficiency at this frequency is 0.03928dB. Figure 3.6 given below shows the polar-plot of directivity at 5.2GHz resonating frequency with main lobe magnitude of 6.0dBi and direction of main lobe is at 2.0 degree. As from figure angular width is 96.4 degree.

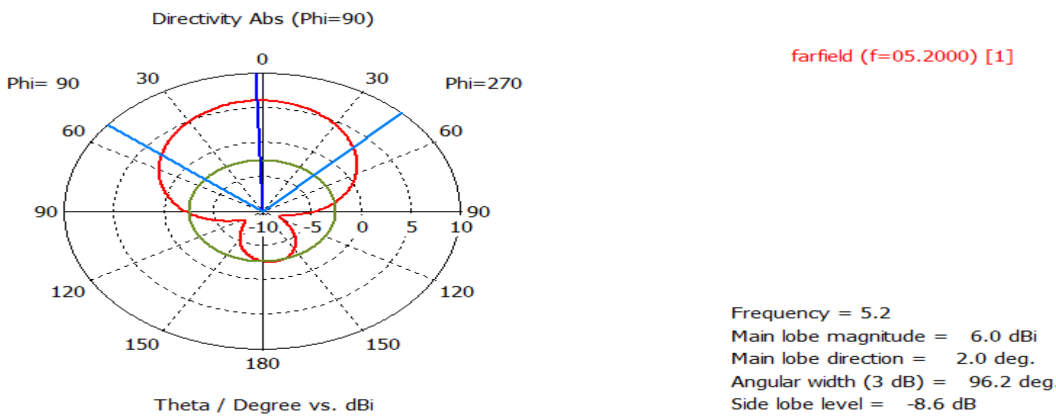


Figure 3.6: Polar-plot at 5.2GHz

3.3.4 VSWR:

The VSWR (voltage standing wave ratio) plot for the design antenna (Aperture feed) is shown in figure 3.7. The value of VSWR is 1.04982 at resonating frequency. A VSWR of 1:1 means that there is no power being reflected back to the source. At a VSWR of 2.0, approximately 10% of the power is reflected back to the source. Not only does a high VSWR mean that power is being wasted, the reflected power can cause problems such as heating cables or causing amplifiers to fold-back.

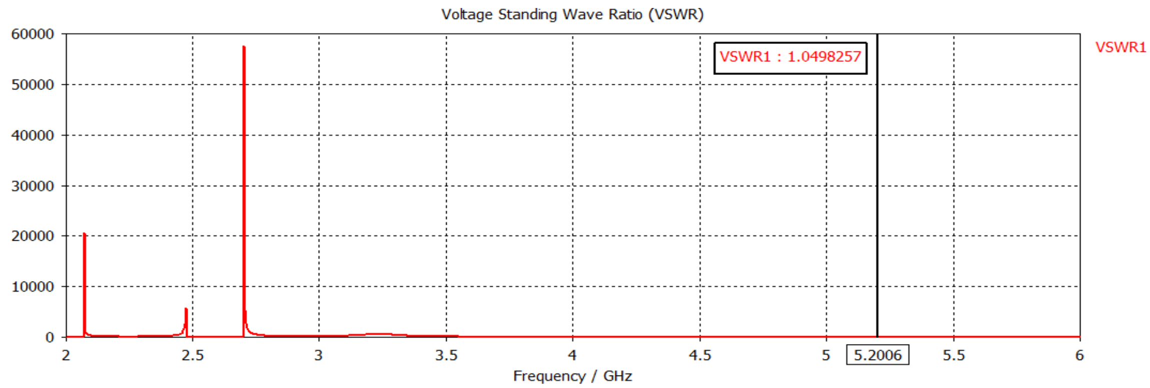


Figure 3.7: VSWR Plot at 5.2GHz

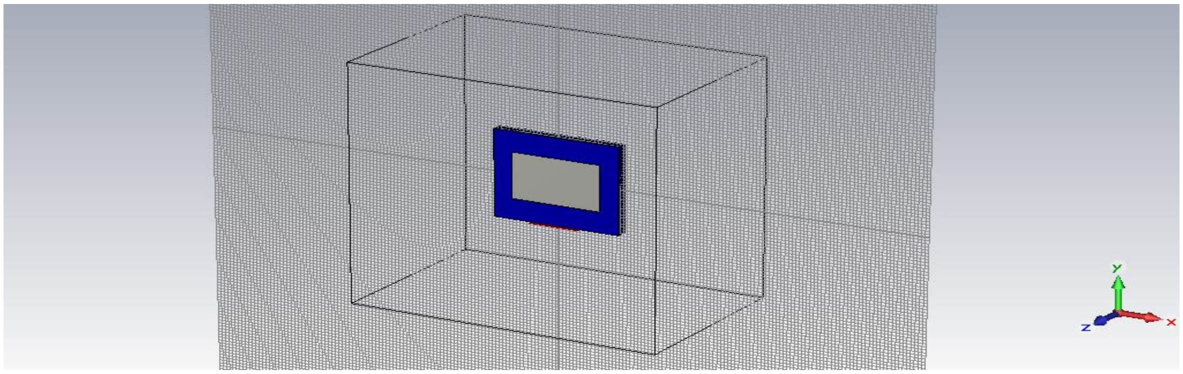
3.4 Design of Single band microstrip antenna at 3.6GHz:

The geometry of proposed antenna which is aperture fed for WiMAX applications is depicted in figure 3.8, (a) shows front view and (b) shows the bottom view of antenna.

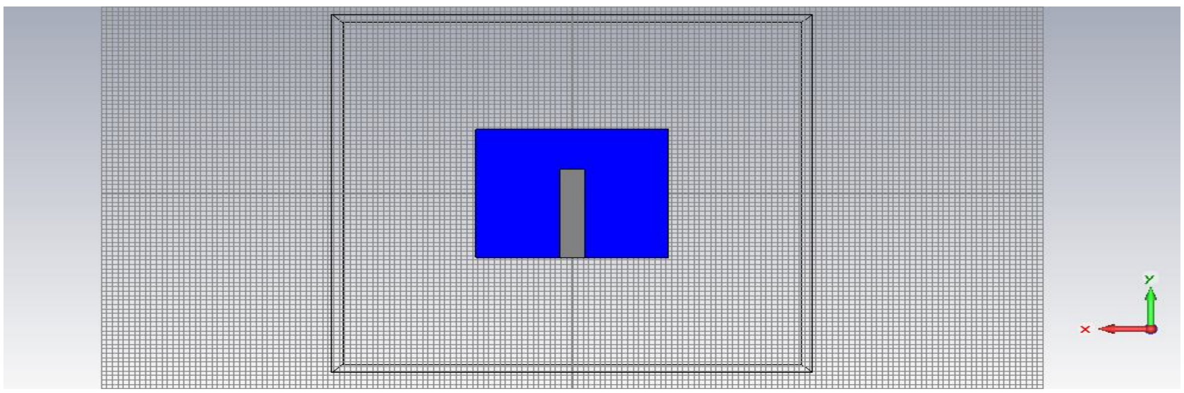
The radiating patch and the microstrip feed line are separated by the ground plane Coupling between the patch and the feed line is made through a slot or an aperture cut in the ground plane. The ground is reduced to provide largest bandwidth. The port assigned to feed is ten times greater than feed width and from minimum value feed, port 3-4 times greater in height.

Table 3.2 Dimension of the designed antenna with aperture feed:

Substrate Material	FR4
Substrate Height	1.570mm
Substrate Size	28.84x34.78mm
Dielectric Constant	4.4
Ground Size	28.84x24.64mm
Patch Size	15.24x24.54mm



(a)



(b)

Figure 3.8: Geometry dimension of antenna (aperture feed) at 3.6GHz (a) front view (b) bottom view

3.4.1 Return Loss and BW:

The simulated value of return loss plot for the designed antenna with aperture feed is -50.29dB shown in figure 3.9 as below. The bandwidth is about 312MHz (3.763-3.451GHz). The designed antenna resonates at 3.6GHz. More negative is the return loss; more is the coupling and therefore more will be the directivity and gain of the proposed antenna in particular direction.

Here, the gain is less due to reduced ground structure, But the bandwidth is more. It is range of frequencies (upper and lower) over which the antenna resonates perfectly. In this case return loss is quite high, thus better coupling is formed.

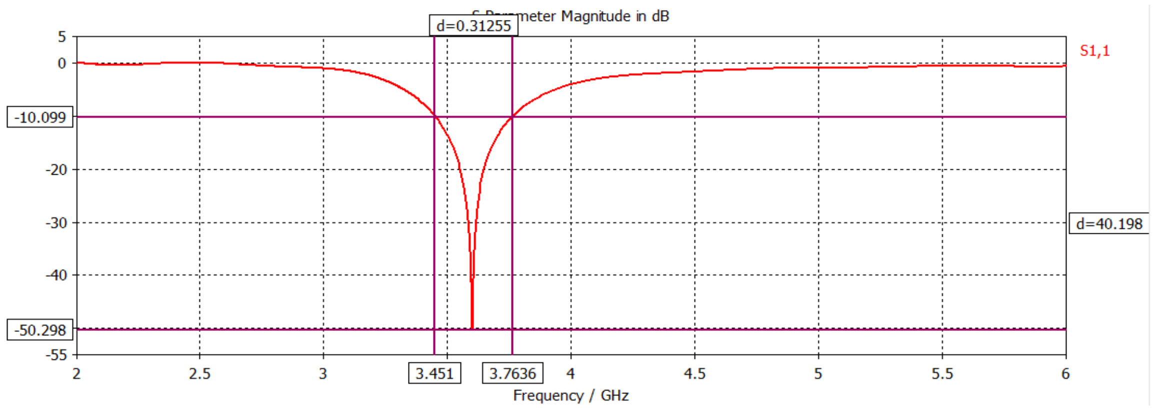


Figure 3.9: Simulated return loss [S11] at 3.6GHz

3.4.2 Smith Chart:

The Smith Chart plot (figure 3.10) represents the antenna impedance varies with frequency. The circle cuts the resistive part of smith chart at 1.01, which is normalized at 50 ohm for perfect matching with 3.6GHz frequency.

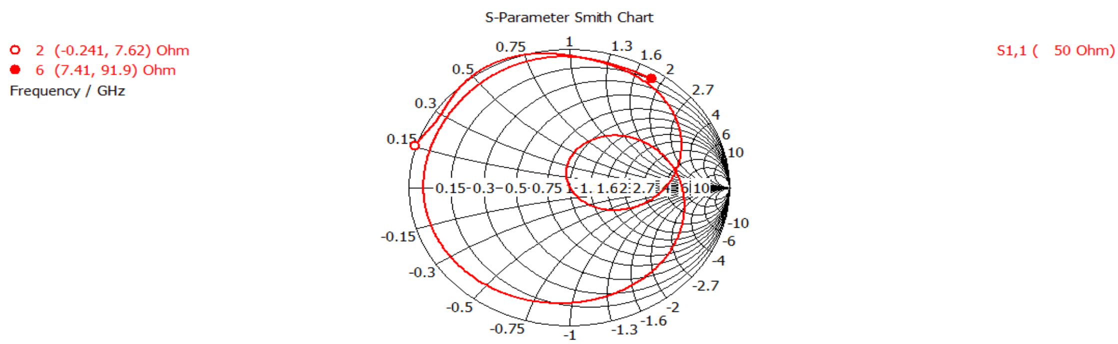


Figure 3.10: Smith chart [S11] at 3.6GHz

3.4.3 Radiation Pattern and Gain:

Figure 3.11 shows the radiation pattern of the proposed antenna with 4.678dB gain at 3.6GHz frequency. The gain of antenna should be greater than 1 (>1), gain is not more because of reduced ground structure but, sufficient at 3.6GHz resonating frequency for required applications.

Figure 3.12 shows the radiation polar-plot, In this picture, the main lobe direction is at 357.0 degree and magnitude is 0.8dB is formed at 3.6GHz. The angular width is 103.7 degree as per simulated results.

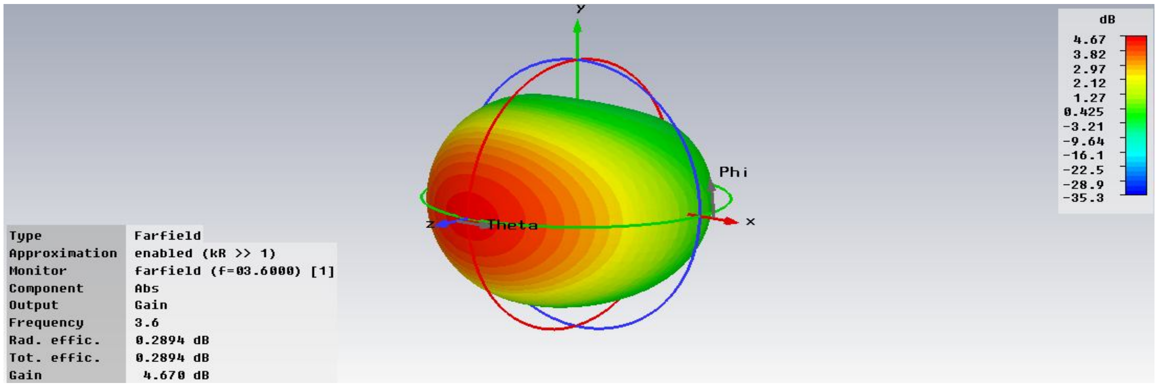


Figure 3.11: 3D-Radiation pattern plot at 3.6GHz

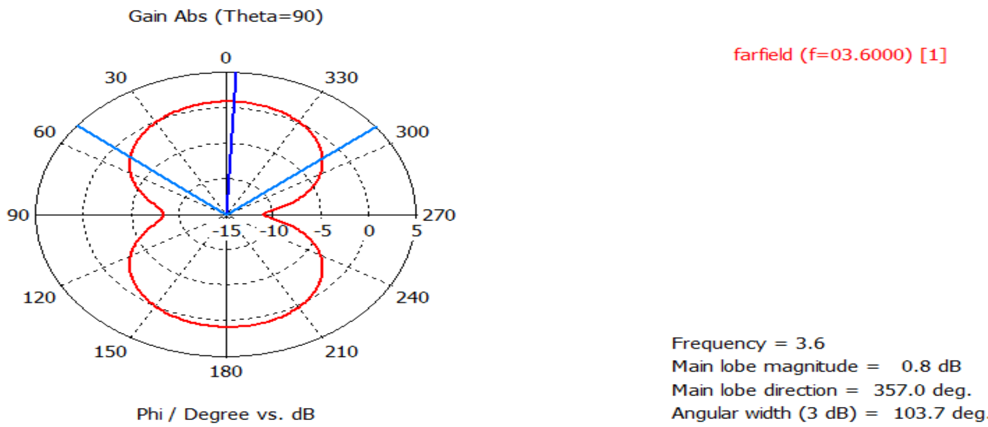


Figure 3.12: Polar-plot at 3.6GHz

3.4.4 Directivity:

Figure 3.13 shows directivity 4.381dBi at 3.6GHz for far-field. The directivity and gain is less, because of reduced ground structure is made at 3.6GHz, but the return loss is more and BW is greater.

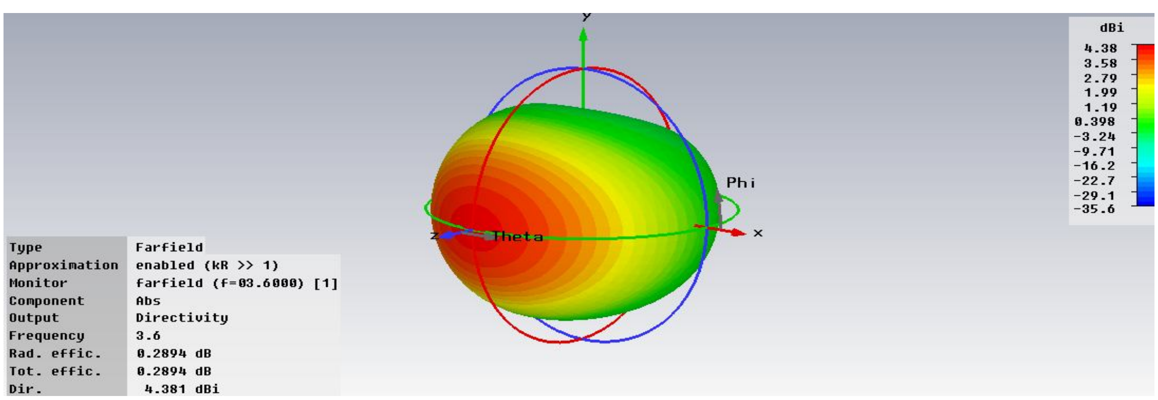


Figure 3.13: 3D-Directivity plot at 3.6GHz

3.4.5 VSWR:

The VSWR (voltage standing wave ratio) plot for the design antenna (Aperture feed) at 3.6GHz is shown in figure 3.14. The value of VSWR is 1.0062 at resonating frequency. A VSWR of 1:1 means that there is no power being reflected back to the source. This is an ideal situation that rarely, if ever, is seen. In the real world, a VSWR of 1.2:1 (or simply 1.2) is considered excellent in most cases. At a VSWR of 2.0, approximately 10% of the power is reflected back to the source. Not only does a high VSWR mean that power is being wasted.

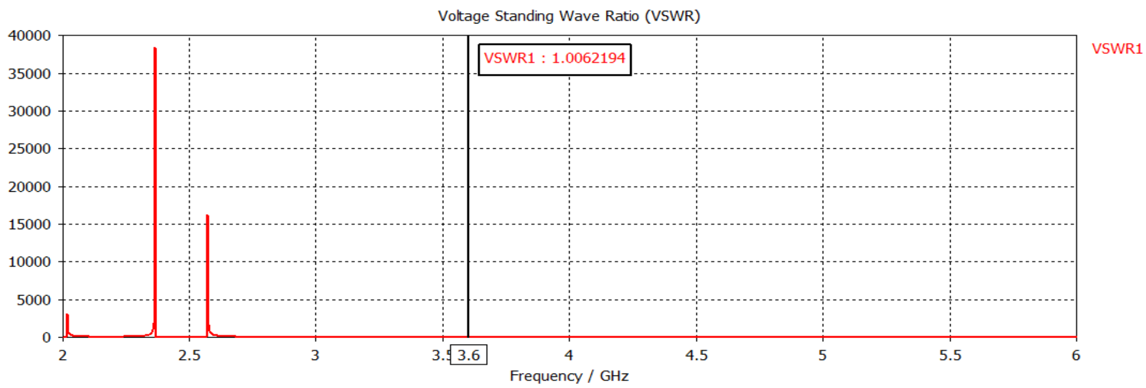


Figure 3.14: VSWR-plot at 3.6GHz

3.5 Performance comparison of different shaped MSA patches with microstrip line feed at 5.8GHz:

3.5.1 Rectangular patch

In presented design the radiating rectangular patch is printed on the top of the substrate and feed line is also given at top and combined with patch. The dimensions of patch are width Wp is 14mm and length Lp is 11.32mm. Substrate used is of same material i.e. FR4 (4.4) and have same height (h=1.570mm).

The width of the feed line is 1mm and towards the patch axis along the negative y-direction is -5.65mm. The design of antenna from CST2010 Microwave studio is shown in Figure 3.15.

This is diagram using CST2009 for aperture coupled antenna. In this case we use FR4 material with h=1.570mm

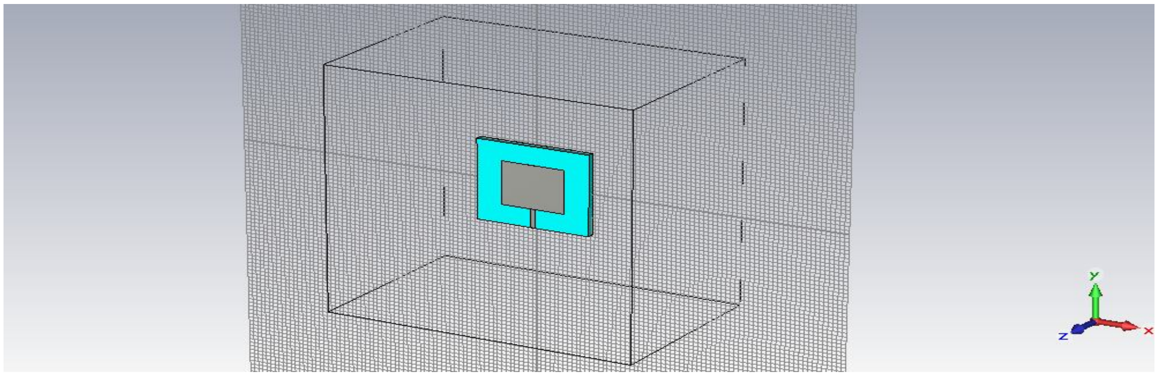


Figure 3.15: Geometry dimension of proposed antenna at 5.8GHz

3.5.1.1 Simulation and experimental results:

The designed antenna shows good bandwidth of 169MHz (5.883-5.714) at return loss of -32.588dB, resonates efficiently at 5.8GHz frequency with impedance of 50 ohms. The simulation result of return loss is shown below in figure 3.16. The impedance matching is done by normalizing at 50 ohms and BW is the range of frequencies over which the antenna resonates effectively. The more negative return loss shows the proper coupling of power with antenna.

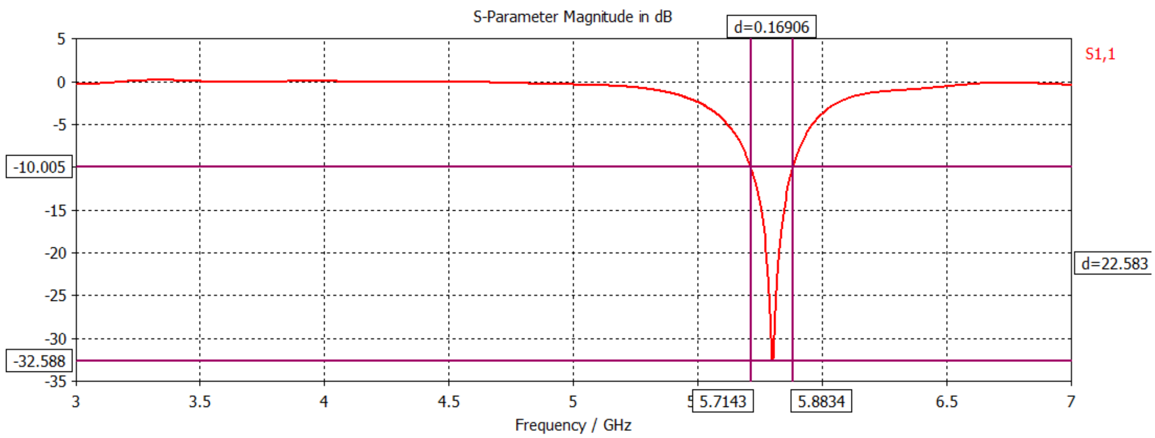


Figure 3.16: Simulated return loss [S11] at 5.8GHz

Figure 3.17 shows radiation pattern with gain is given i.e. gain= 7.874dB. Radiation efficiency is also more i.e. 1.257dB.

The gain of the proposed antenna is more as compared to isotropic antenna which means that more the gain, more directional is the antenna. Also, the bandwidth of the antenna proposed is good, so the proposed antenna is useful for the WLAN, covers the band (5.714 GHz to 5.883 GHz).

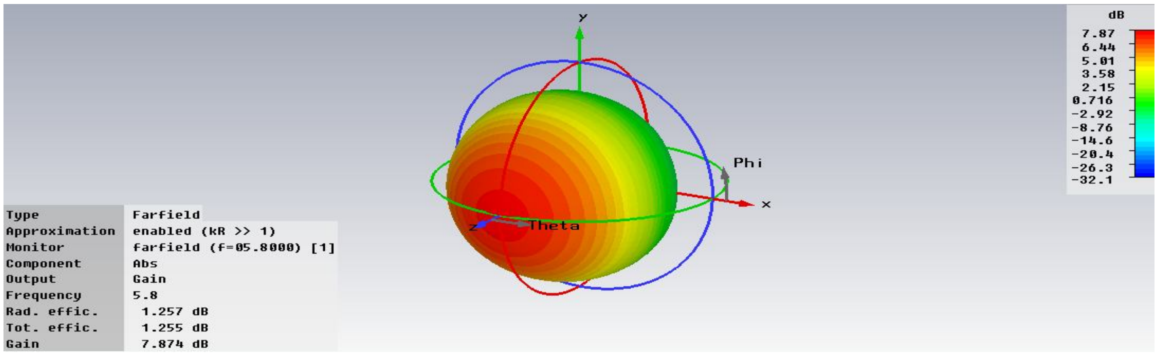


Figure 3.17: Gain with Rectangular Patch at 5.8GHz

3.5.2 Triangular-patch

The dimensions of patch are the top radius of triangle is 8.66mm and bottom radius is 8.66mm. Substrate used is of same material. The width of the feed line is 1mm and towards the patch axis along the negative y-direction is -4.2mm. The design of antenna is shown in figure 3.18. The different shape is created using different shapes in CST-2010 microwave studio.

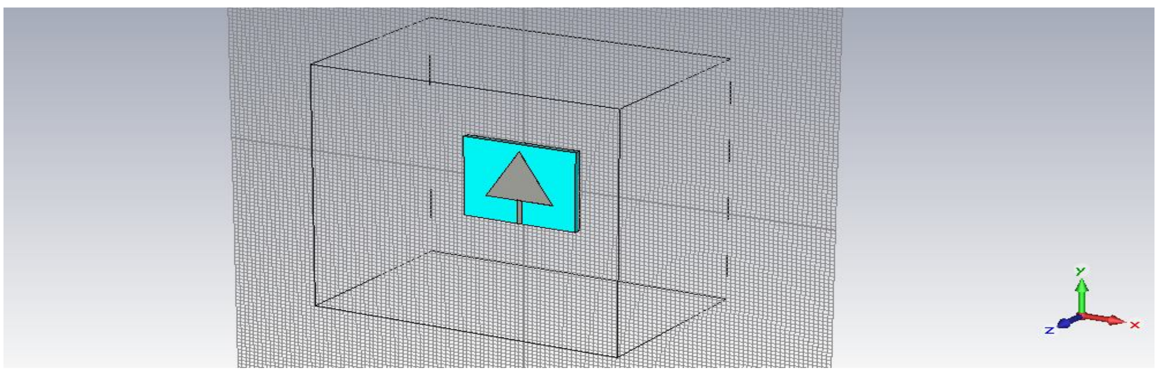


Figure 3.18: Design of Triangular-patch Antenna at 5.8GHz

3.5.2.1 Simulation and experimental results of design:

The designed antenna shows good bandwidth of 106MHz (5.853-5.746) at return loss of -40.435dB, resonates efficiently at 5.8GHz frequency with impedance of 50 ohms. The simulation results of return loss is shown below in figure3.22 and gain in figure3.19. The maximum gain is obtained at resonating frequency. The vale of gain is 7.59dB. The proper impedance is formed after normalizing the results at 50 ohms and got better results. The BW is greater than 100, thus antenna effectively resonates at 5.8 GHz and covers the band from 5.746GHz to 5.853GHz that is enough for WLAN applications.

The radiation efficiency is 1.179dB with same total efficiency. As from the figure, it is clear that the return loss is more, thus power coupled to antenna is better, so give the better performance.

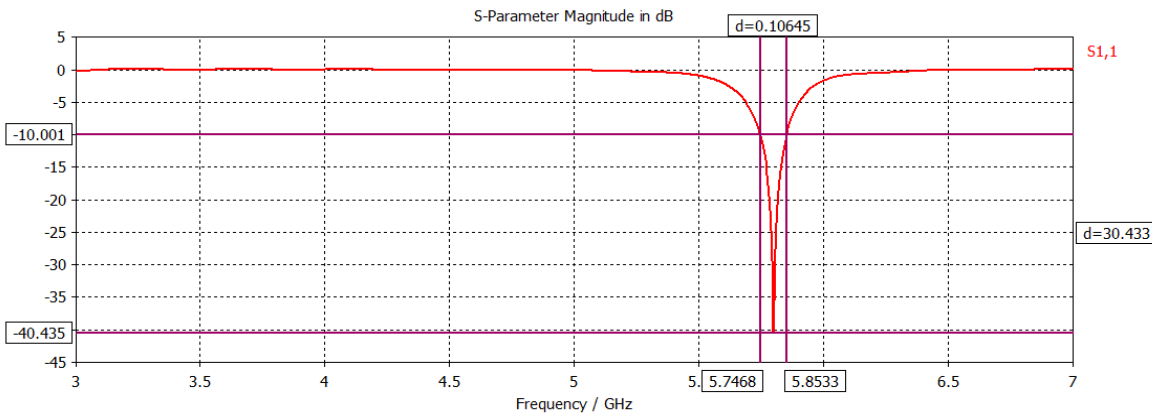


Figure 3.19: Result of Return loss at 5.8GHz

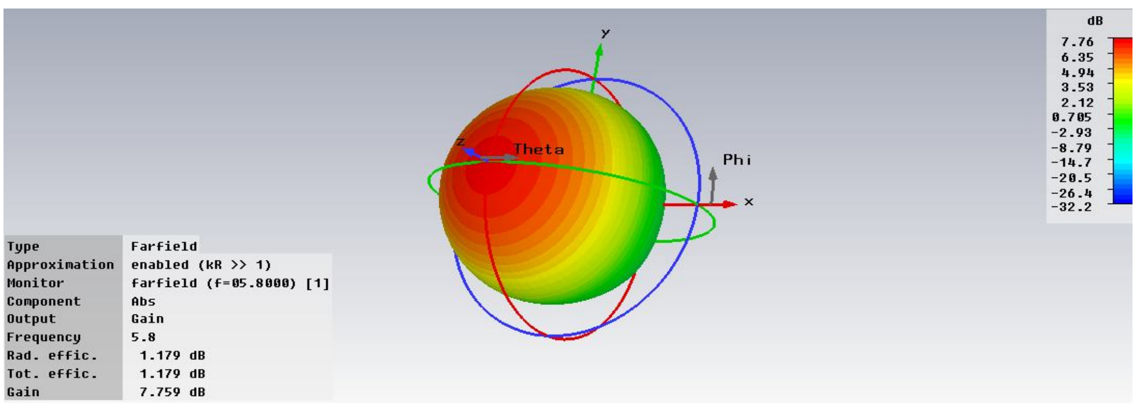


Figure 3.20: Gain of Antenna with Triangular patch at 5.8GHz

3.5.3 Circular patch

The patch with outer radius of circle is 6.709mm and inner radius is 0. Substrate used is of same material. The width of the feed line is 0.56mm and towards the patch axis along the negative y-direction is -5.65mm.

The design of antenna is shown in figure 3.21. The circle shape is created by selecting circle in CST2010 software, and the material used for design is same i.e. FR4 with dielectric constant of 4.4 and available height of substrate is h= 1.570mm. Figure gives the geometry of antenna.

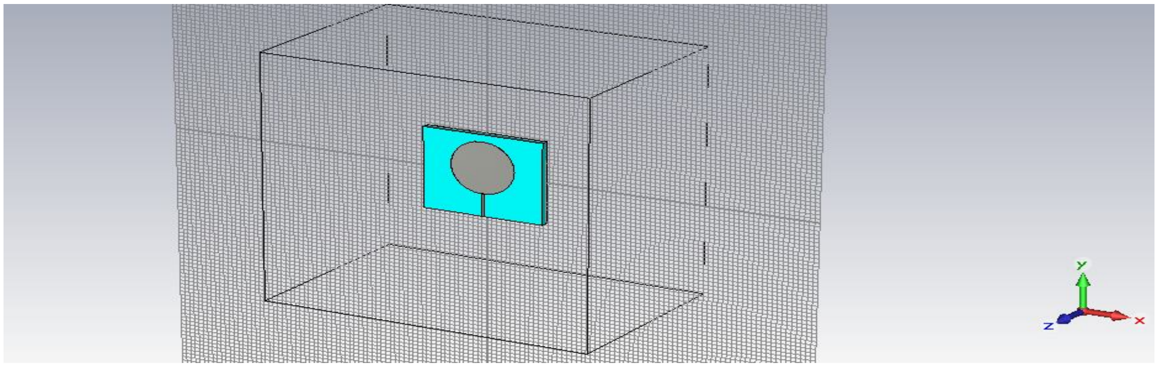


Figure 3.21: Design at 5.8GHz with circular patch antenna

3.5.3.1 Simulation and experimental results of design:

The designed antenna shows bandwidth of 133GHz (5.862-5.729) at return loss of -37.98dB, resonates efficiently at 5.8GHz frequency with impedance of 50 ohms. The simulation results of return loss and gain are shown below in figure 3.22 and radiation pattern in figure3.23. The impedance is get normalized at 50ohm and thus band obtained is effective covers the range from 5.729GHz to 5.862 GHz. This band is sufficient to cover WLAN applications. The return loss is more for better coupling

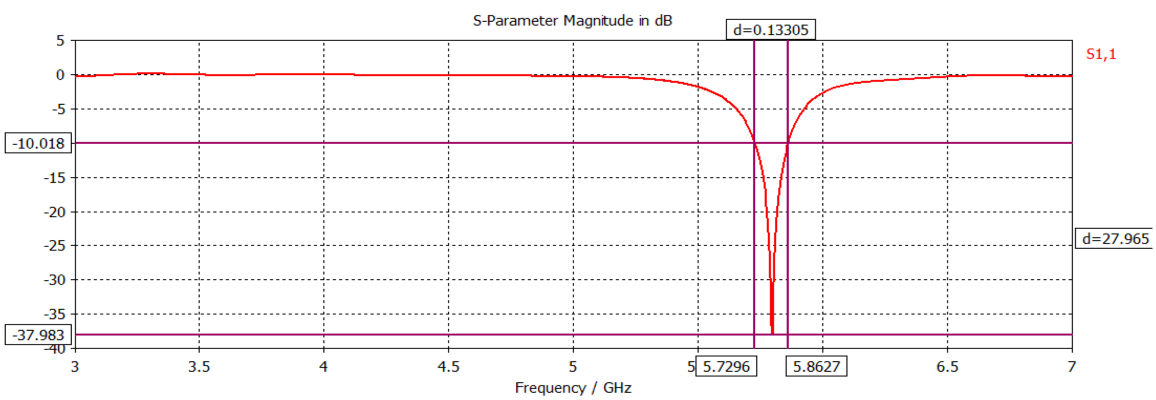


Figure 3.22: Return loss plot at 5.8GHz

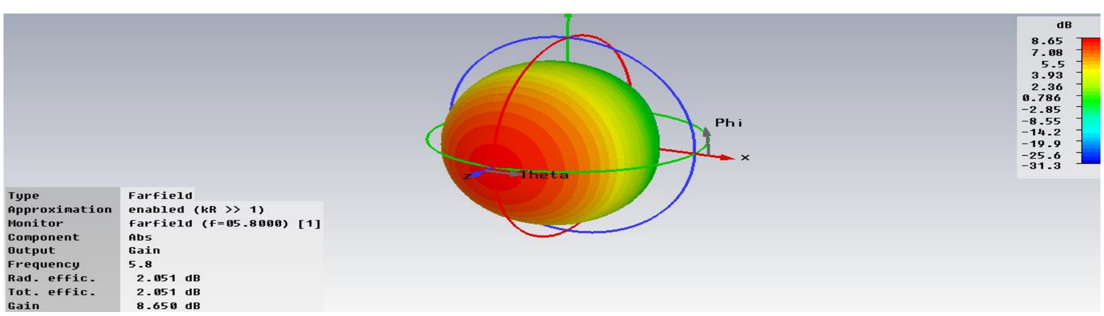


Figure 3.23: Gain with Circular Patch at 5.8GHz

The gain of the antenna at 5.8GHz frequency is more i.e. 8.650dB and radiation efficiency is about 2.051dB.

3.5.4 Pentagonal- patch

The outer radius of circle is 7.72mm and inner radius is 7.72.Substrate used is of same material. The width of the feed line is 0.4mm and towards the patch axis along the negative y-direction is -6.2mm. The design of antenna is shown in figure 3.24. The pentagonal shape is created from circle by selecting number of segments; Here at software selected segments are 5 for pentagonal shape.

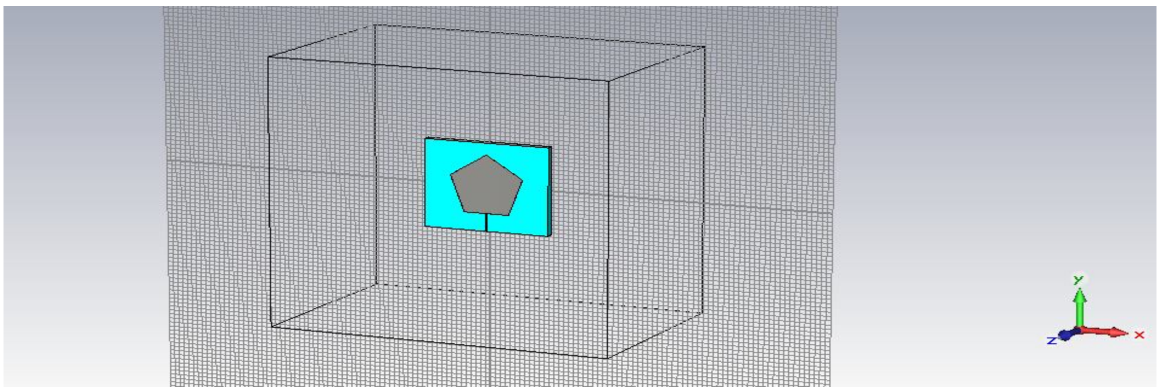


Figure 3.24 Design of pentagonal-patch antenna at 5.8GHz

3.5.4.1 Simulation and experimental results of design

The designed antenna shows good bandwidth of 1338MHz (5.865-5.731) at return loss of -44.53dB, resonates efficiently at 5.8GHz frequency with impedance of 50 ohms after normalizing the results with 50 ohms. The simulation result of return loss is shown below in figure 3.25. Due to maximum RL, the power coupling is better.

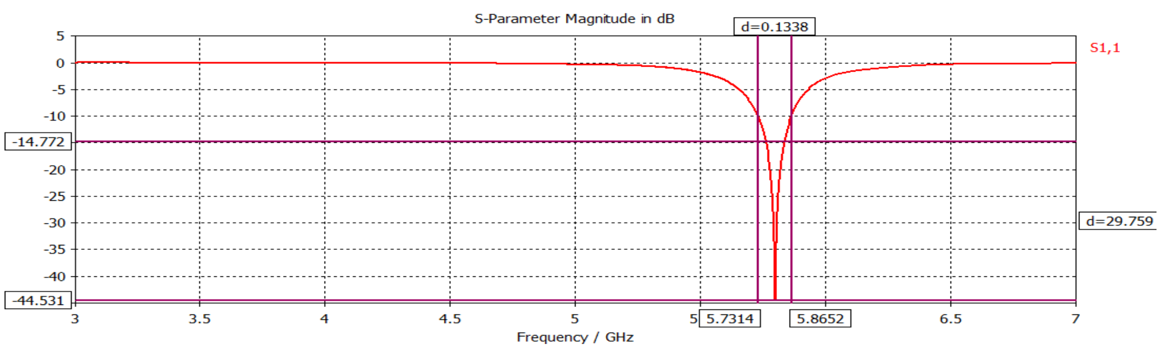


Figure 3.25: Result of Return loss at 5.8GHz

And figure 3.26 show the gain is maximum. The value of gain is 8.555dB. The radiation efficiency is about 1.923Db with same total efficiency.

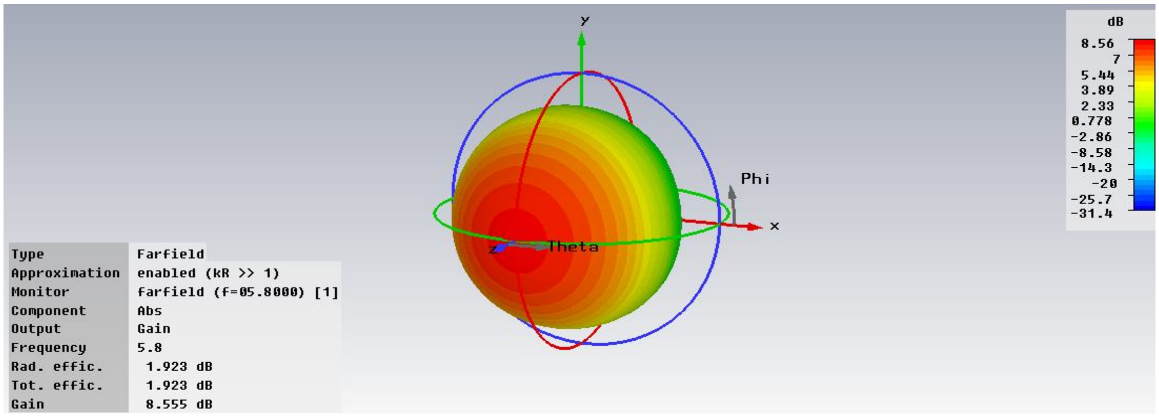


Figure 3.26: Gain of circular patch at 5.8GHz

Now, the comparison between all these feeding techniques can be summarized in the tabulated form in table 3.3.

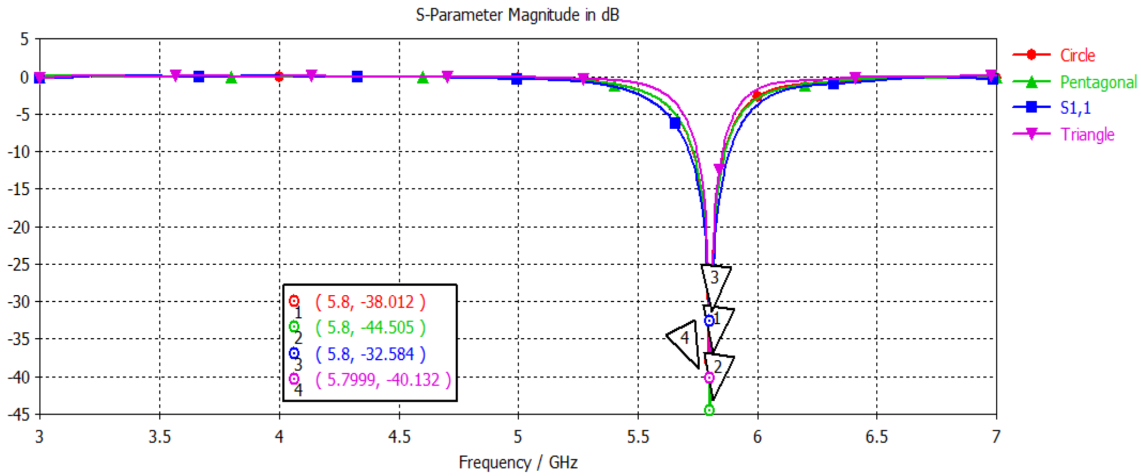


Figure 3.27: Combined return loss [S11] of patches at 5.8GHz

Now the comparison of return loss plot with microstrip line feeding technique using different patch shapes is shown by drawing all return loss plots on a single graph as shown above in figure 3.27. Hence, rectangular patch provides the largest bandwidth and triangular shaped patch provides the least bandwidth. The maximum of the return loss [S11] at frequency 5.8GHz is also studied here, i.e. the maximum return loss is due to pentagonal patch and minimum using rectangular patch, but gives more BW. The combined comparison is discussed in below Table 3.3.

Table1 3.3 Comparison of gain and directivity using different patches:

Parameters	**Rectangular -patch**	**Triangular-patch**	**Circular-patch**	**Pentagonal-patch**
Frequency(GHz)	5.8	5.8	5.8	5.8
Gain(dB)	7.879	7.759	8.650	8.555
Directivity(dBi)	6.617	6.580	6.599	6.632
Bandwidth(MHz)	169	107	133	133

This table concludes that, the gain is maximum at pentagonal patch thus maximum directivity obtained. But many of cases, the rectangular patch is used, because of simple to design and fabricate.

Conclusion:

In this chapter, a simple rectangular microstrip patch antenna is designed for a single frequency 5.8GHz with microstrip line feed technique. The parameter return loss [s11] and gain have been compared for each different shape of patch. Here, this chapter can conclude that the maximum bandwidth can be achieved by pentagonal shaped patch with more directivity.

Chapter 4

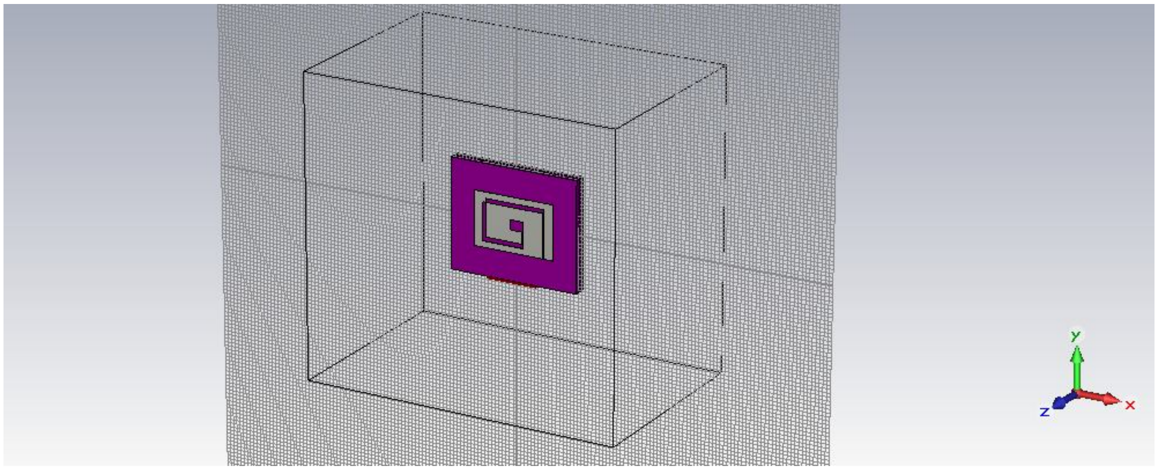
Dual band antenna design and parametric study

Wireless communication is very famous and widely used and with introduction of new application, operation at two or more discrete bands and wide bands are desired. In such cases, a patch capable of operating in multiple bands is desirable. There are number of methods of obtaining dual band or multi-bands and wide band have been developed.

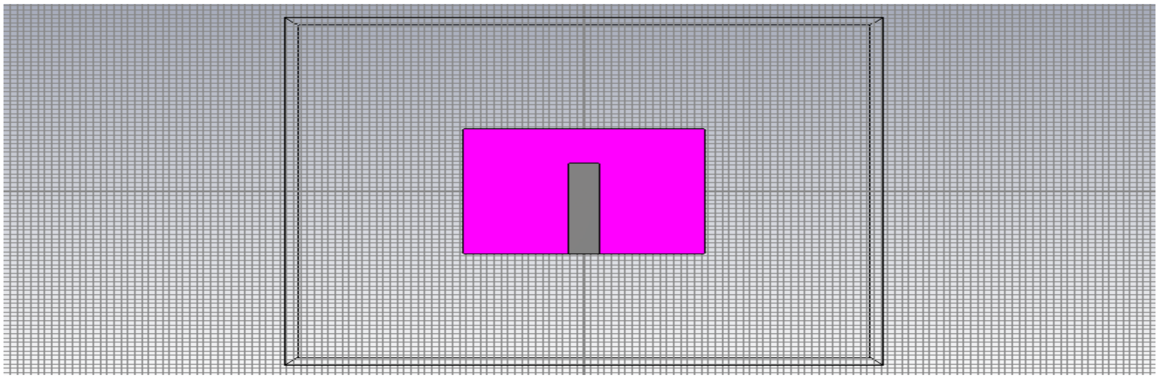
4.1 Dual band antenna design:

An aperture coupled single band antenna at 3.6GHz for WLAN application was designed, as discussed in chapter 3.Now, this design with reduced ground is loaded with slots at non-resonating side of the patch and by combining all slots, It forms a G-shape slot at patch and make it to resonates at two frequency bands namely 3.43-3.73GHz and 4.98-5.59GHz for WLAN/WiMAX applications. One extra slot is loaded in ground to increase the gain and return loss of an antenna. Figure4.1 shows the geometry of antenna for desired applications (a) front view (b) bottom view.

When the dual band antenna is excited by Gaussian pulse at the waveguide port, it gives the enough bands to cover WiMAX/WLAN applications.

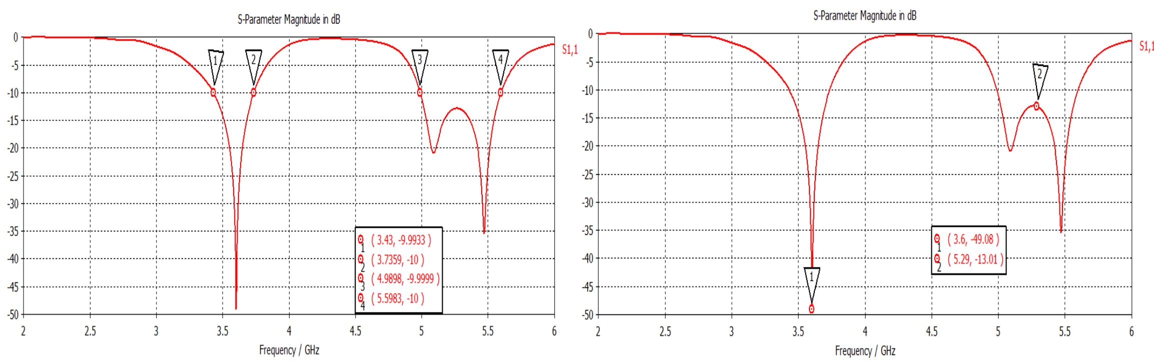


(a)



(b)

Figure 4.1: Geometry dimension of proposed dual band antenna at 3.6GHz (aperture feed) (a) front view (b) bottom view



(a) (b)

Figure 4.2: Simulated return loss [S11] at 3.6GHz

From figure 4.2, it shows that the antenna covers a lower band of 3.437 to 3.735GHz of bandwidth 304Db with return loss -49.08dB in figure 4.2(a).

And the higher band of 4.989 to 5.59GHz of bandwidth 608dB with return loss -13.01dB, as given in figure 4.2(b). Figure 4.3 and shows the smith chart results at 50ohm impedance. And, it is also depicts that the antenna resonates at 3.6GHz and 5.29GHz for dual band operation. From smith chart, it consists of two circles are very clear, at 5.29GHz it gives wide band with impedance 50.75ohm, thus form heart shaped circle formed and at 3.6GHz, impedance is 49.78ohm. These frequencies are perfectly matched at 50ohm after normalizing and give better results. The Smith Chart plot represents that how the antenna impedance varies with frequency. As, it is visible from the figure 4.3

that the circle cuts the resistive part of smith chart at two ends i.e. 0.58 and 0.98. Also, the loop between the two ends gives us an idea about the bandwidth which means that the proposed antenna is a wide dual band antenna resonating at frequencies 3.6GHz and 5.29GHz.

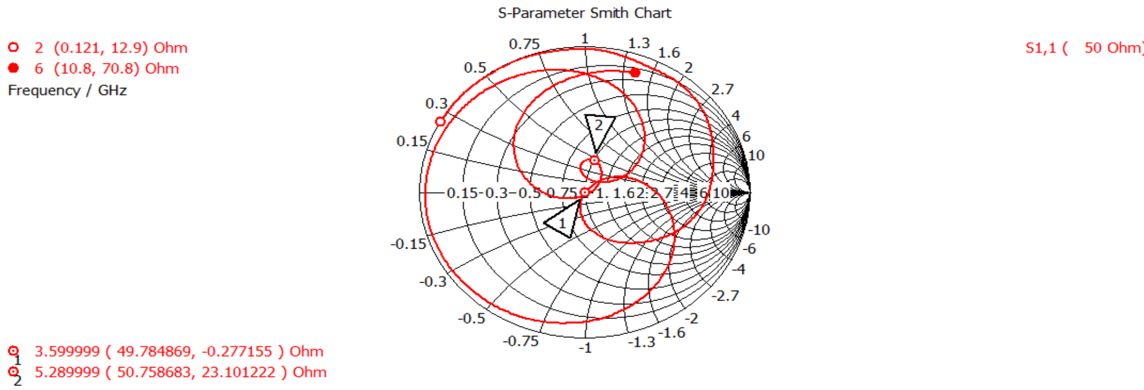


Figure 4.3: Smith chart [S11] at 3.6GHz

4.2 Parametric study of dual band antenna:

The parametric study of proposed antenna is done using CST2010 microwave studio. The effect of changing different slots, slot of ground and study is also done on feed is given below:

4.2.1 Effect of change in PL1:

The variations in the resonating frequency with PL1 (first slot in patch) as shown in figure 4.4. When the value of PL1 increased from 8.3mm to 8.5mm, there is a decrease in the resonant frequency and impedance matching of the antenna.

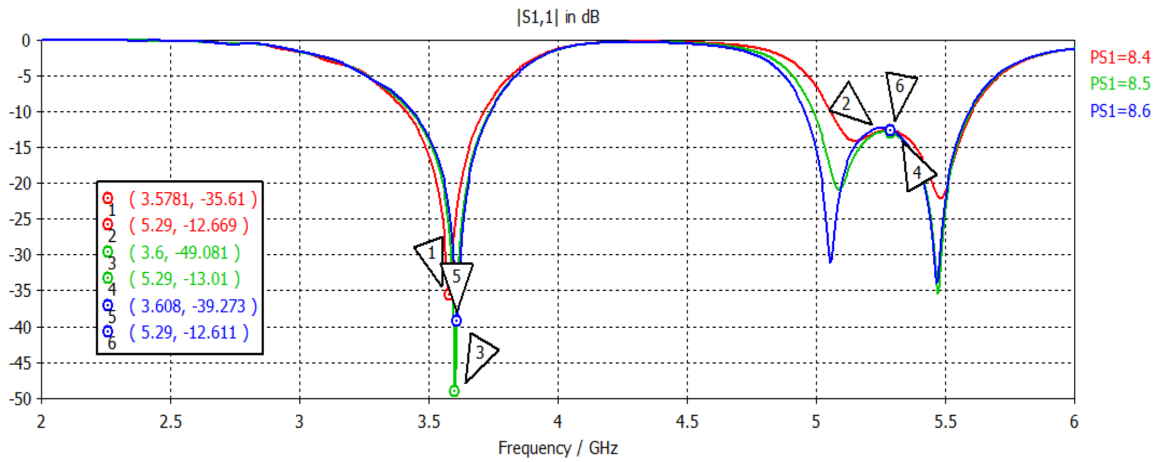


Figure 4.4: Variation of S-parameter first slot of the patch at 3.6GHz

The optimum value of PL1 is 8.5mm is chosen, because at this point perfect frequency formed as shown in figure 4.5.

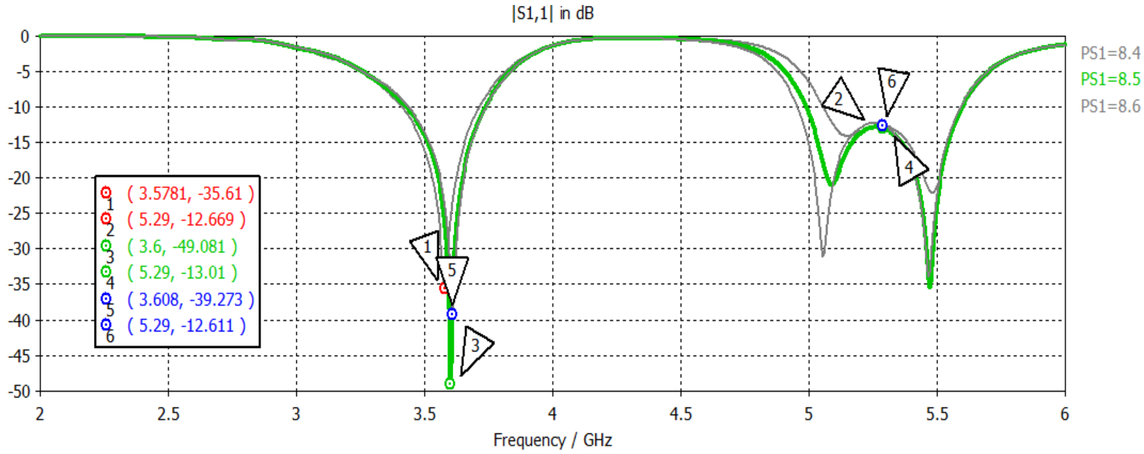


Figure 4.5: Selected value of PS1

Figure 4.6 shows the surface current of the antenna at 3.6GHz. The slot 1 is responsible for radiations at the higher frequency band, and the current due to slot 3 seems to be low flowing current. The maximum surface current at 3.6GHz is 78.3808A/m due to slot1 and responsible for first band i.e. it gives 3.6GHz frequency band.

The field monitor is hi field at 3.6GHz and monitor the maximum current at 3.6GHz and shows the part of maximum current.

Side strip shows the level of current i.e. from minimum (green color) to maximum (red color) current value.

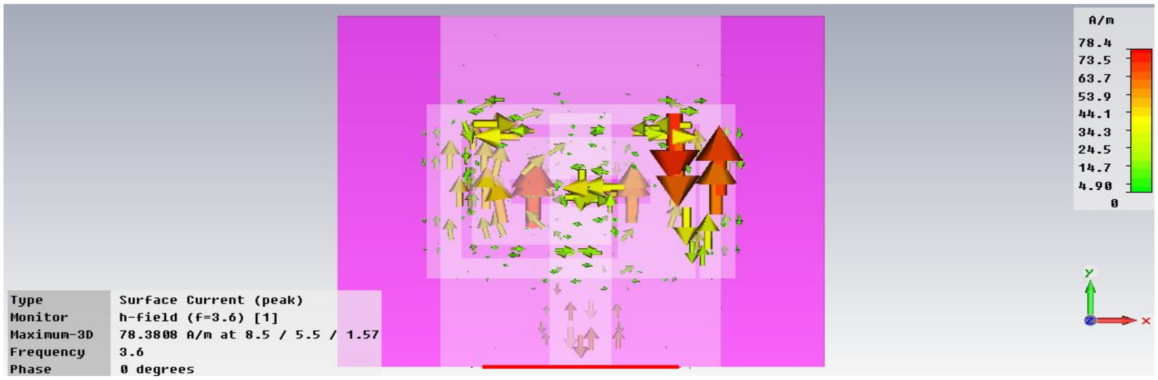
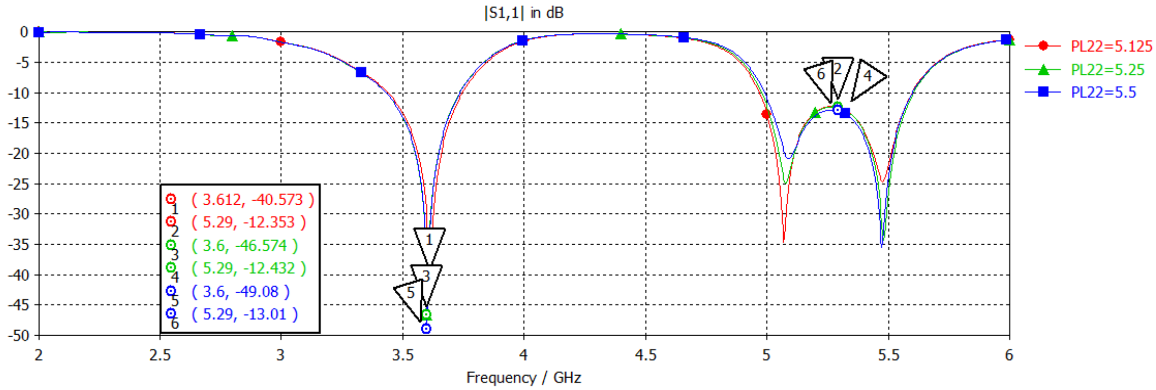


Figure 4.6: Surface current of the antenna at 3.6 GHz.

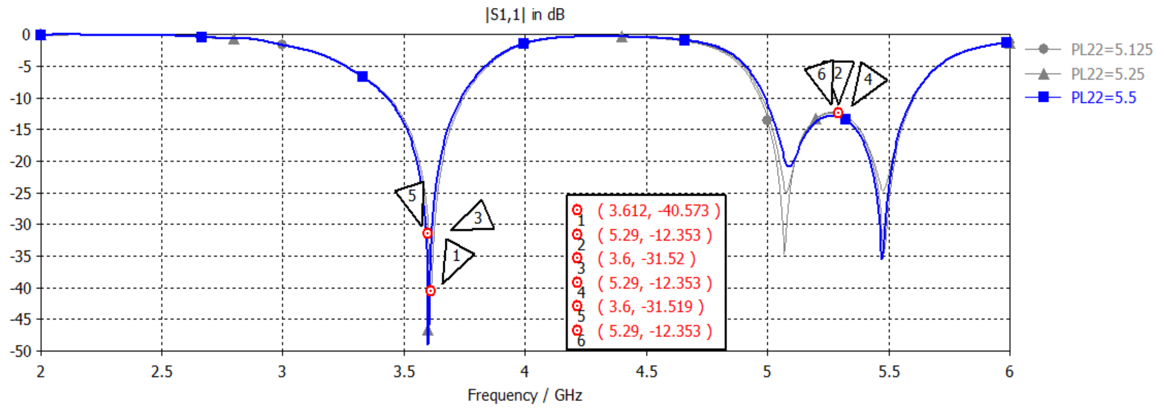
4.2.2 Effect of change in PL2 (Second slot of patch):

The variations in the resonating frequency with PL2 (second slot in patch) and with keeping the other parameters constant, as shown in figure 4.7(a) (b). As the value of PL2 increased from 5mm to 5.5mm, there is a decrease in the resonant frequency and impedance matching of the antenna.

The return loss increases and BW also increases with PL2 (slot in patch) width. The optimum value of PL2 is 5.5mm is chosen as shown in figure 4.6 (b), because at this point perfect frequency formed.



(a)



(b)

Figure 4.7: Variation of S-parameter with change in width of the ground slot (a) sweep result (b) selected value

4.2.3 Effect of change in PL3 (Third slot in patch):

The variations in the resonating frequency with PL3 (third slot in patch) as shown in figure 4.8. When the value of PL3 increased from 8 to 8.5, there is not more effect in the resonant frequency, but affects the return loss of the antenna.

The optimum value of PL3 is 8.5mm is chosen, because at this point perfect frequency formed and BW formed

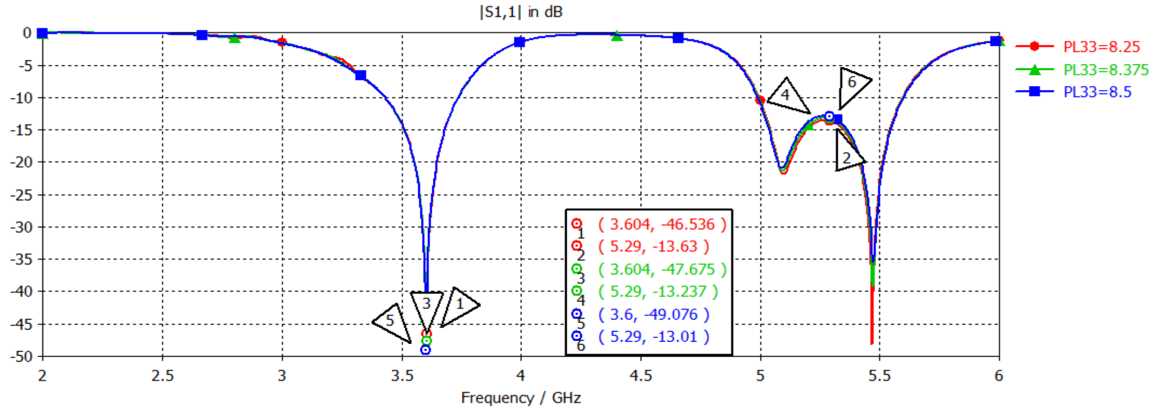


Figure4 .8: Variation of S-parameter with change in width of the ground slot (a) sweep result (b) selected value

4.2.4 Effect of change in PL5 (Centre slot in patch):

Figure 4.9 shows that, at PL5=0.75mm the optimum value at 3.6GHz and at 5.29GHz obtained. As shown in graph, the arrow5 gives the maximum return loss and good BW.

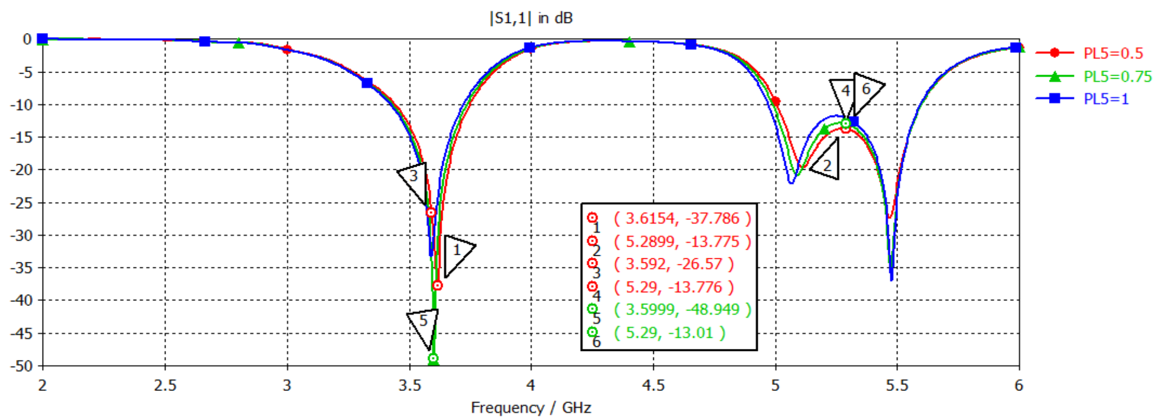


Figure 4.9: Variation with PL5 (ground slot)

Figure 4.10 shows the surface current of the antenna at 5.29GHz. The slot1 is again responsible for radiations at the second band, and the current due to slot3 seems to be low flowing current and slot5 is responsible for the wide band at 5.29GHz. The maximum surface current at 5.29GHz is 75.9255A/m.

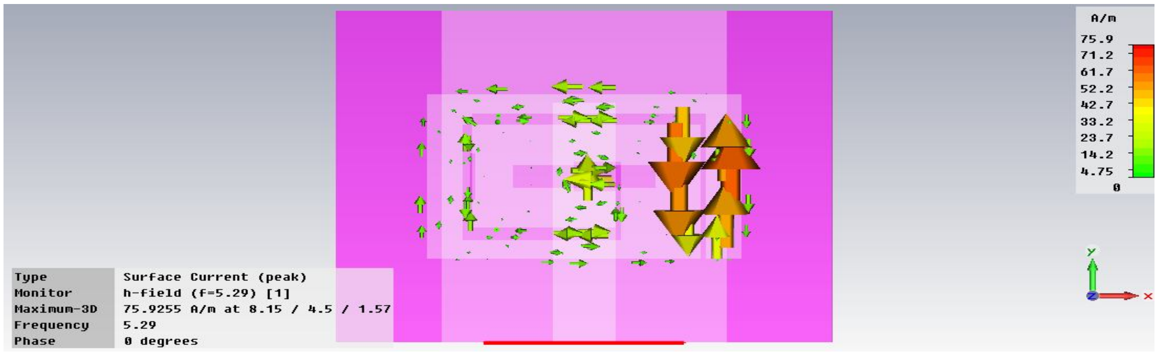
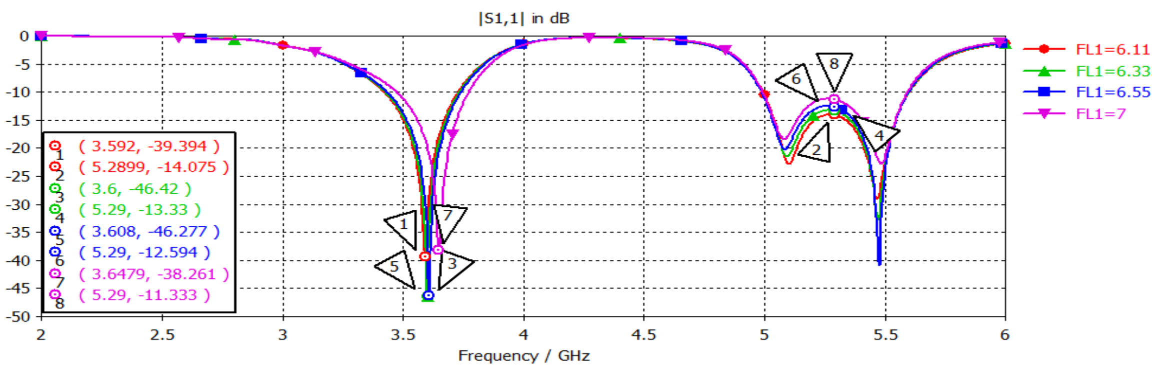


Figure 4.10: Surface current of the antenna at 5.29GHz.

4.2.5 Effect of change in feed length (FL) and width (FW) :

The variations in the resonating frequency with FL (feed length)as shown in figure 4.10. When the value of FL increased from 6mm to 7mm, there is a increase in the resonant frequency and impedance matching of the antenna is obtained at FL=6.33mm is selected value as shown is figure 4.11(a) (b).



(a)

Different arrows (1,2,3,4,5,6,7,8) shows different value, like 7 and 8 gives the values at 3.6GHz and 5.29GHz is -38.26 and -11.33. Similarly using 3 and 4 arrows maximum and optimum value i.e. -46.42 and -13.33 obtained.

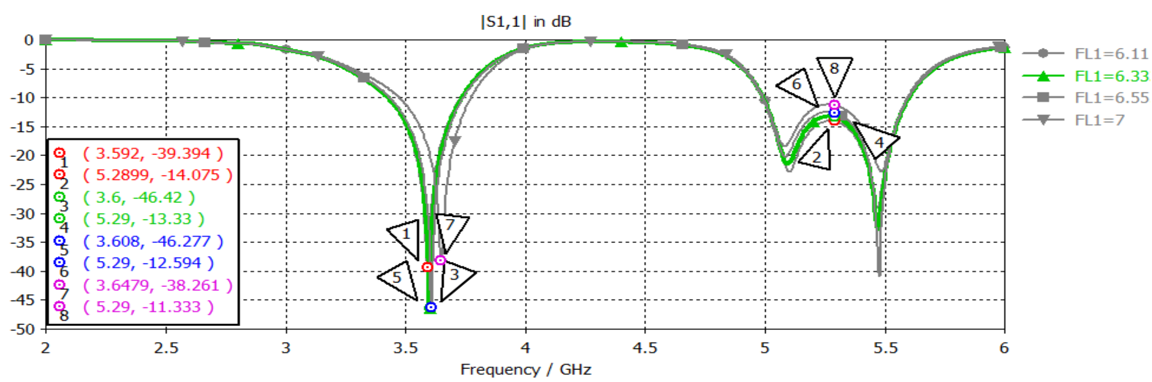


Figure 4.11: Variation in length of the feed stub (a) sweep result (b) selected value

Now, the effect on feed width is studied, below the plot is given at different feed width values and differentiated with different curve style. From figure 4.12, 2.2mm is selected, because gives required value at resonating frequencies. (3.6/5.29GHz).

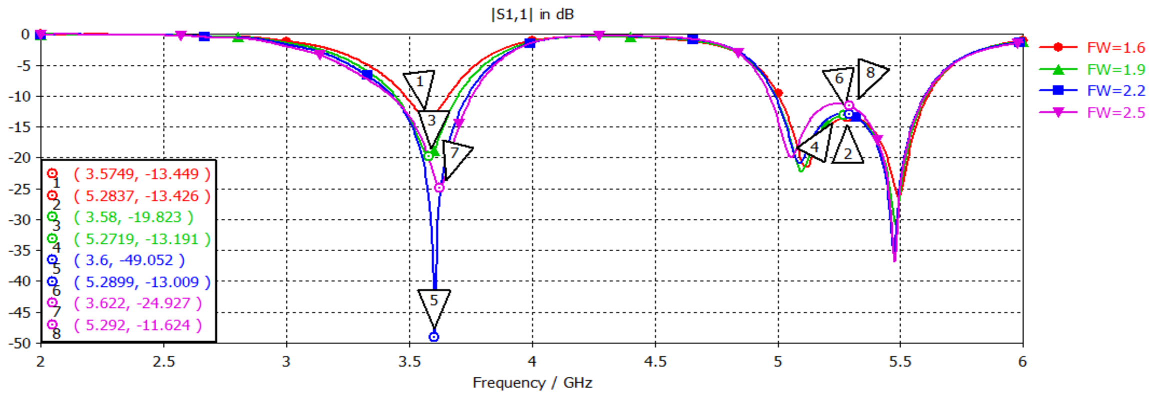


Figure 4.12: Variation of S-parameter with change in feed width

4.2.6 Effect of change in slot length (SL) and width (SW):

The variations in SL (slot length) as shown in figure 4.13. When the value of SL increased from 3mm to 5mm, As the slot length increases, the frequency decreases and return loss increases of the antenna. At minimum value of SL give poor response, but at SL=5mm the optimum value is obtained.

Similarly, in case of slot width the optimum value is SW is 1mm, as shown in figure 4.14 (a) (b).

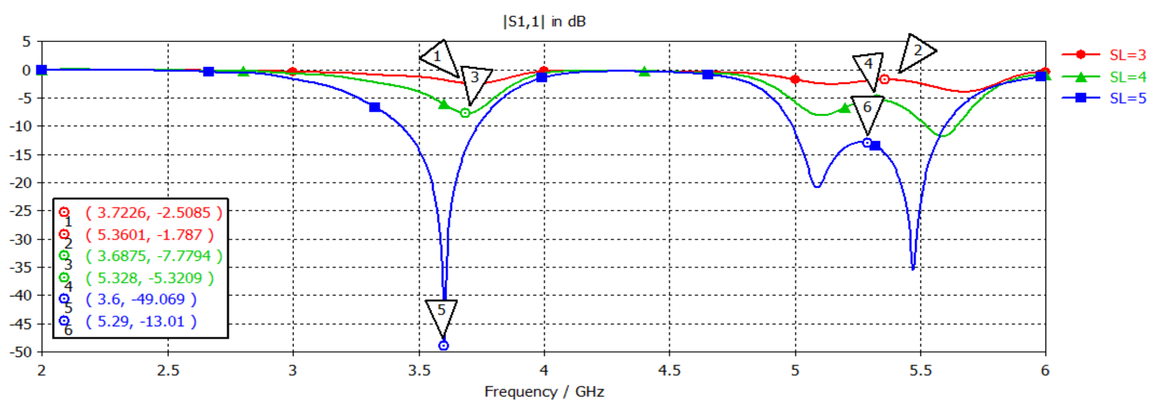
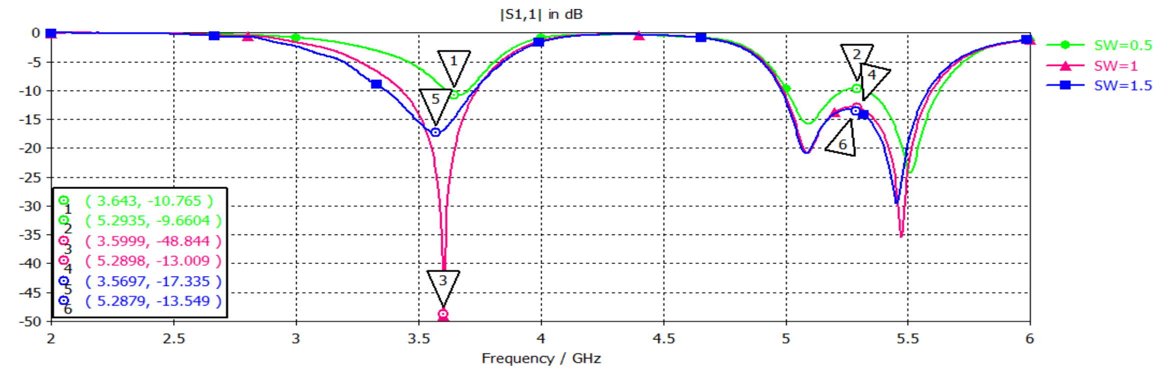
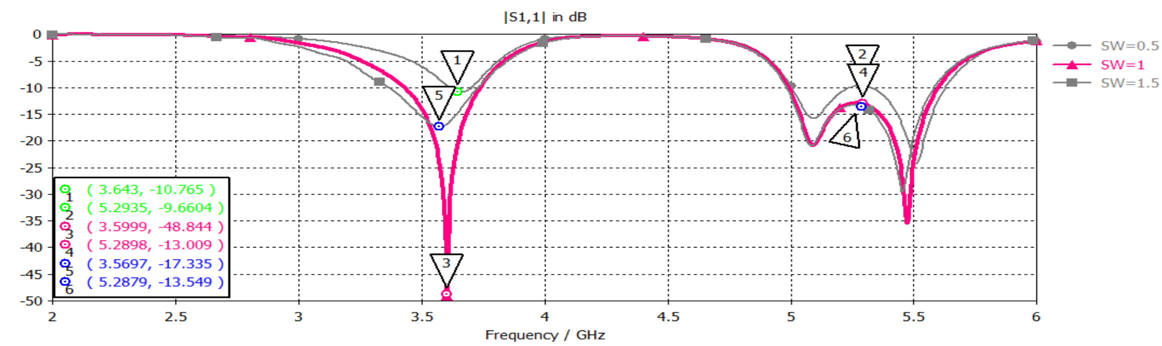


Figure 4.13: Variation of S-parameter with ground slot length

The optimum value is SW=1 chosen, because give perfect results. In this sweep, as the SW increases frequency shifts towards left side and increases the return loss also.



(a)



(b)

Figure 4.12: Variation of S-parameter with change in width of the ground slot (a) sweep result (b) selected value

4.3 Comparison of Single and Dual band antenna:

In chapter 3, single band antenna is discussed at 3.6 GHz, This chapter gives the dual band with wide band at 3.6GHz and 5.29GHz (covers 5.0 to5.3GHz and 5.3to 5.6GHz) is designed. Figure4.13 shows the comparison between single band and dual band antenna.

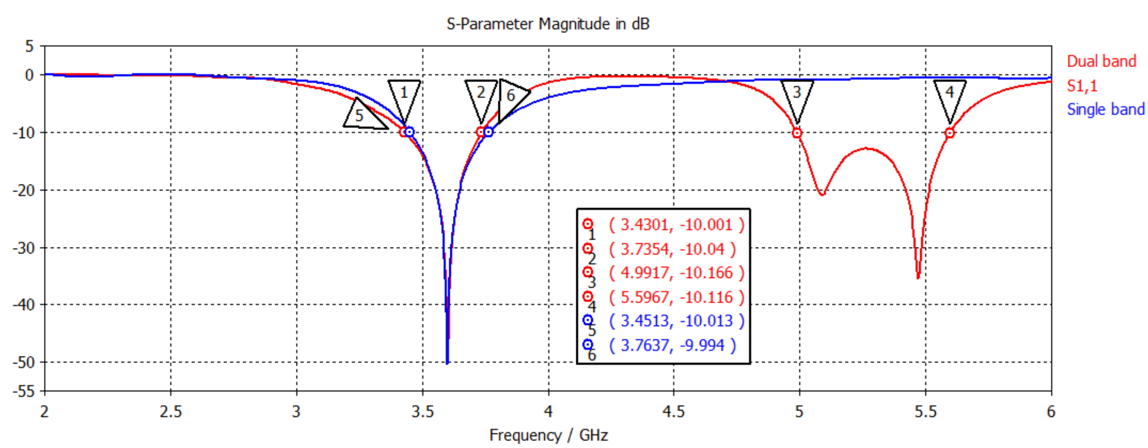


Figure 4.13: S-parameters of single and dual band

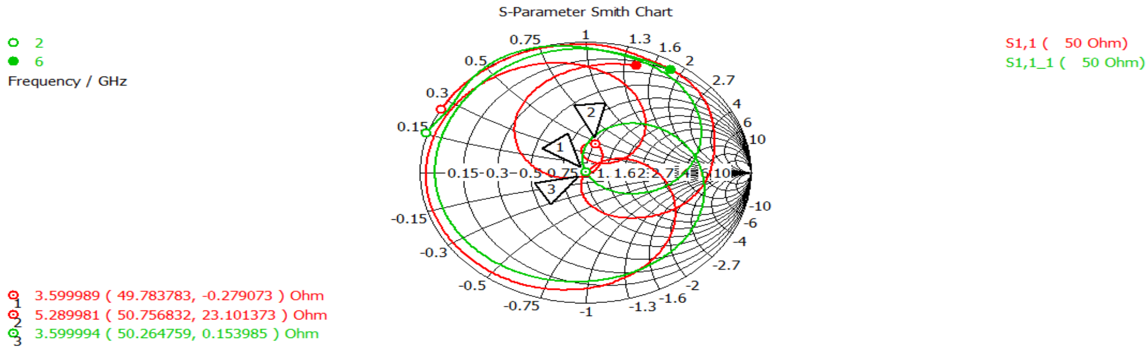


Figure4.14: Smith chart with comparison of two antennas

Single band antenna resonates in range from 3.4513GHz-3.7637GHz with bandwidth of 312MHz; this is enough band for WiMAX application. The return loss is obtained is maximum i.e. -50.28dB. The design for dual band antenna, it covers two bands of resonating frequencies at 3.6GHz and 5.29GHz, and range of bands is from 3.4301GHz-3.7354GHz (BW = 3.5MHz) and another range is from 4.9917GHz-5.5967GHz (BW = 605MHz). Return loss is obtained maximum at 3.6GHz i.e. -49dB and minimum RL at 5.29GHz i.e. -13.01dB respectively. Figure 4.14 shows the smith chart.

The impedance matching for single band antenna is at 50.26ohm, this is perfect match. Similarly, for dual band impedance is matched at 49.78ohm at 3.6GHz and at 5.29GHz, it is obtained as 50.75ohm i.e. also a perfect match of impedance (all are near 50ohm). The comparison for both antennas in terms of gain, directivity, E-field and H-field is listed in the Table 4.1

Table 4.1 (Comparison between single and dual band)

Parameters	**Single band**	**Dual band**	
Frequency(GHz)	3.6	3.6	5.29
Directivity(dBi)	4.381	3.892	3.954
Gain(dB)	4.670	4.388	4.389
E-field(dBV/m)	19.43	19.15	18.92
E-field(dBW/m2)	-32.09	-32.37	-32.60

The directivity of the antennas is above 4dBi in each case, makes it suitable for the wireless applications. They have gain of above 4dB. The E-field, H-field at a distance of 1metre are also listed. The table 4.1 shows that the directivity of the antenna at 3.6GHz and 5.29GHz as 4.388dBi and 4.389dBi, and gain as 4.388dB and 4.389dB respectively. These values are fair enough to be used for the WiMAX and WLAN applications.

Conclusion

Hence, it has been shown that microstrip antenna can be fed by aperture coupled feeding technique with reduced ground structure for wide and dual band operation. The microstrip patch antenna can have multiple resonant frequency i.e. we can design a single microstrip patch antenna for multiple bands for WLAN/WiMAX applications.

Chapter 5

Dual band antenna design with DGS

In this chapter, design procedure of a microstrip patch antenna with aperture and microstrip line feeding techniques and their simulation results are discussed for WLAN applications. The effect of change patch change in DGS ground and different shaped patch etc. are discussed.

Multiband of the antenna is also possible by using defected ground structure (DGS) which disturbs the shield current distribution in the ground plane which further influences the input impedance and current flow of the antenna providing a bandpass or bandstop like filter and other microwave circuits [35,36]. Method of calculating the characteristics impedance of transmission line with DGS is given by J. Lim, J. Lee, J. Lee, S.-M. Han, and D. Ahn. and Y. Jeong [37].

A microstrip patch antenna using the defected ground structure (DGS) to suppress higher order harmonics is presented. An H-shaped defect on the ground formed [38].

5.1 Dual band antenna design with DGS: This design with defected ground structure is loaded with slots at the patch and thus, It forms a H-shaped patch and make it to resonates at two frequency bands namely 2.4GHz and 5.8GHz for WLAN applications. Figure5.1 shows the geometry of antenna for desired applications. When the dual band antenna is excited by Gaussian pulse at the waveguide port, it gives the enough bands to cover WLAN applications.

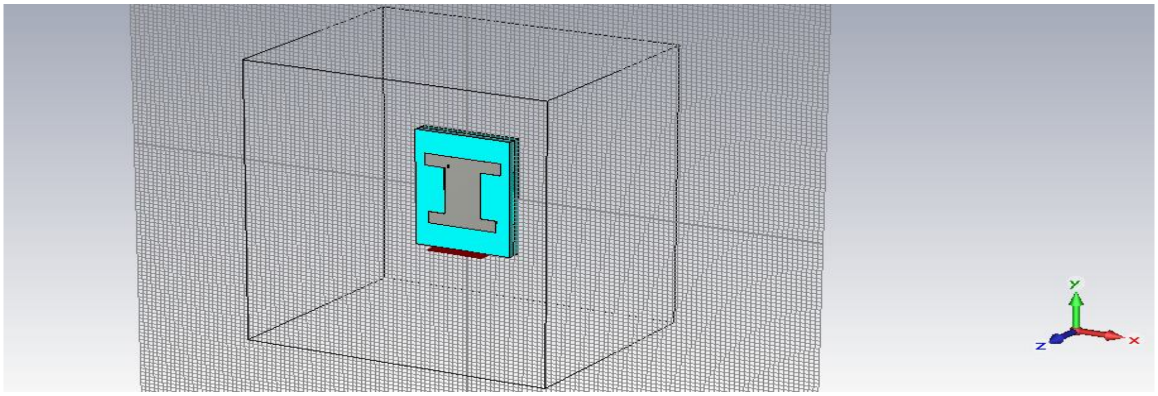


Figure 5.1: Geometry dimension of proposed dual band antenna (aperture feed)

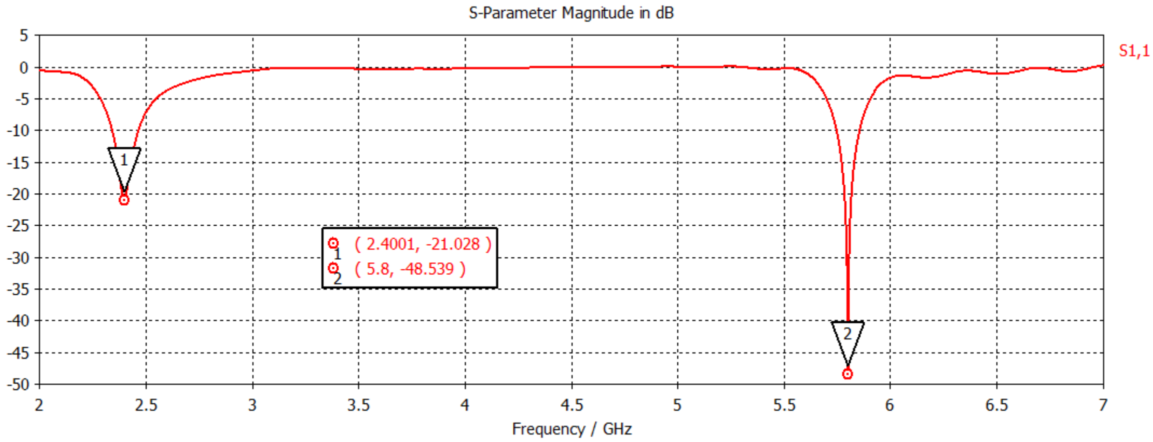


Figure5.2: Simulated return loss [S11] 1 at 2.4GHz AND 2 at 5.8GHz

5.1.1 Return Loss:

From figure 5.2, it shows that the antenna covers a lower band of 2.336 to 2.464GHz of bandwidth 128 dB with return loss -21.028Db resonating at 2.4GHz, And the higher band of 5.748 to 5.853GHz of bandwidth 105dB with return loss -48.53dB is resonating at 5.8GHz as given above.

5.1.2Smith chart:

Figure 5.3 and shows the smith chart results at 50ohm impedance. And, it is also depicts that the antenna resonates at 2.4GHz and 5.79GHz for dual band operation. From smith chart, it consists of two circles, one is at 2.4GHz gives impedance of 55.26ohm and 5.79GHz gives 50.37ohm.

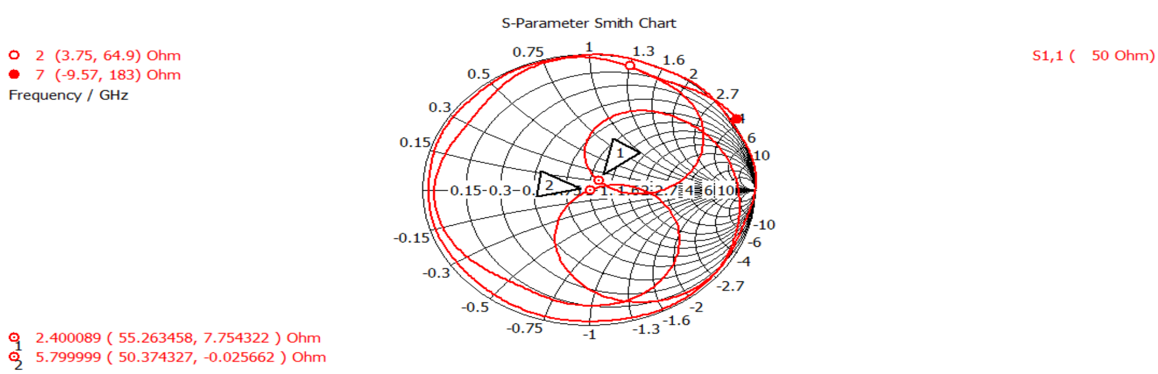


Figure 5.3: Smith chart

5.1.3 Radiation Pattern:

Figure 5.4 shows the radiation pattern plot for the proposed antenna with 1.962dB i.e. approximately equal to 2dB gain at 2.39GHz frequency.

Figure 5.5 shows the polar plot of gain, give main lobe magnitude of 2.0dB at 2.4GHz

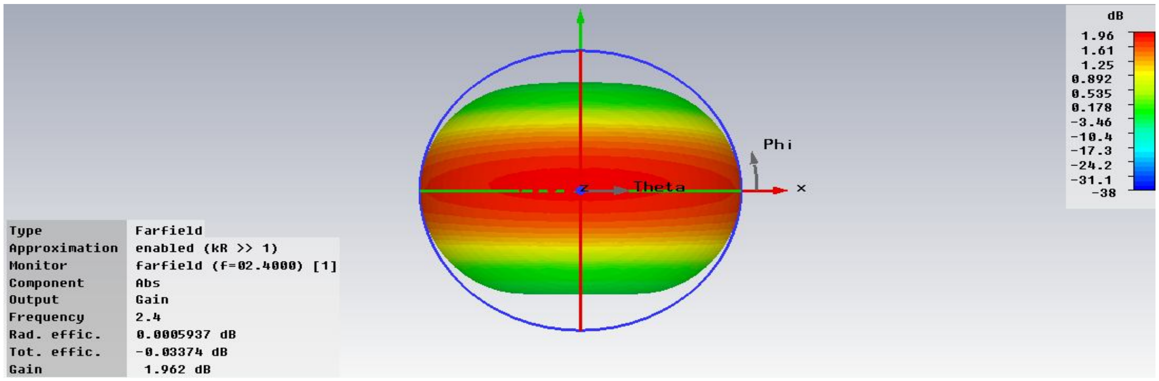


Figure 5.4: 3d Radiation pattern plot [2.4GHz]

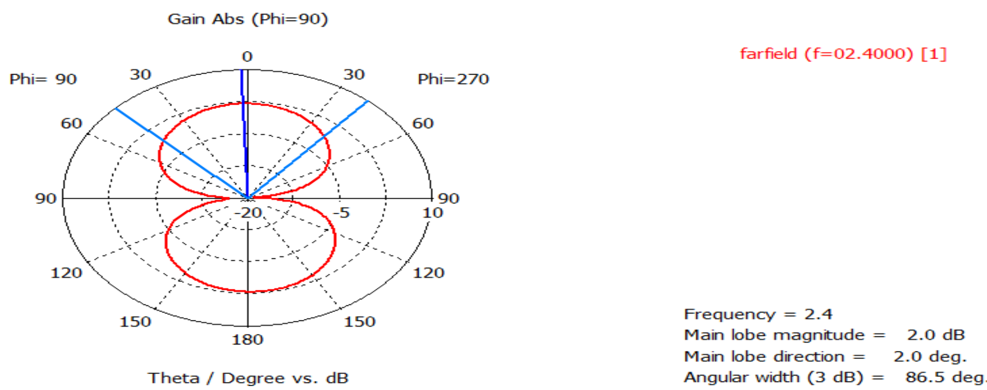


Figure 5.5: 3 Polar-plot of gain [2.4GHz]

Figure 5.6 shows the radiation pattern plot for the proposed antenna with 3.468dB gain at 5.8GHz frequency. Figure 5.7 shows the polar plot of gain, give main lobe magnitude of 3.5dB at 5.8GHz and angular width is of 51.3 degree with -3.2dB side lobe level at resonating frequency.

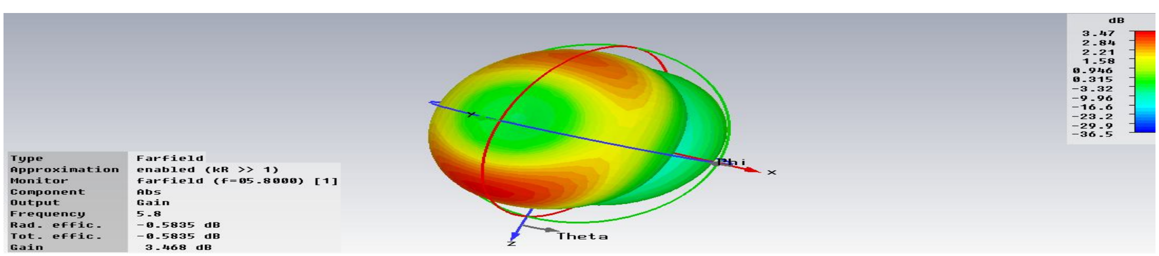


Figure 5.6: 3D-plot of gain [5.8GHz]

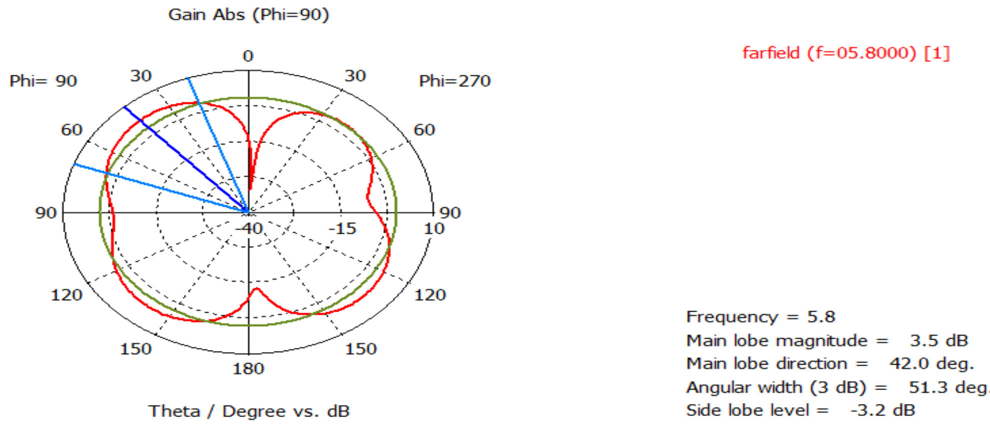
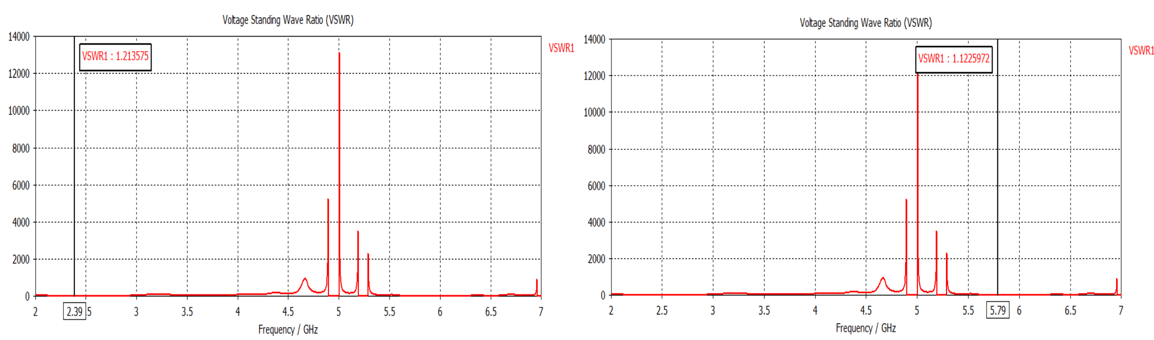


Figure 5.7: Polar-plot of gain [5.8GHz]

5.1.4 VSWR

The VSWR plot for the design antenna (Aperture feed) at 2.4GHz and 5.79GHz is shown below in figure 5.8. The value of VSWR is 1.2135 at 2.39GHz and 1.1225 at 59.GHz i.e. the resonating frequencies. A VSWR of 1:1 means that there is no power being reflected back to the source. This is an ideal situation that rarely, if ever, is seen. In the real world, a VSWR of 1.2:1 (or simply 1.2) is considered excellent in most cases.

Not only does a high VSWR mean that power is being wasted, the reflected power can cause problems such as heating cables or causing amplifiers to fold-back , this will affects the results.



(a) (b)

Figure 5.8: VSWR-plot (a) 2.39GHz (b) 5.79GHz

This table given below shows the result comparison at both frequencies (2.4/5.8GHz) in terms of Gain, VSWR, Bandwidth.

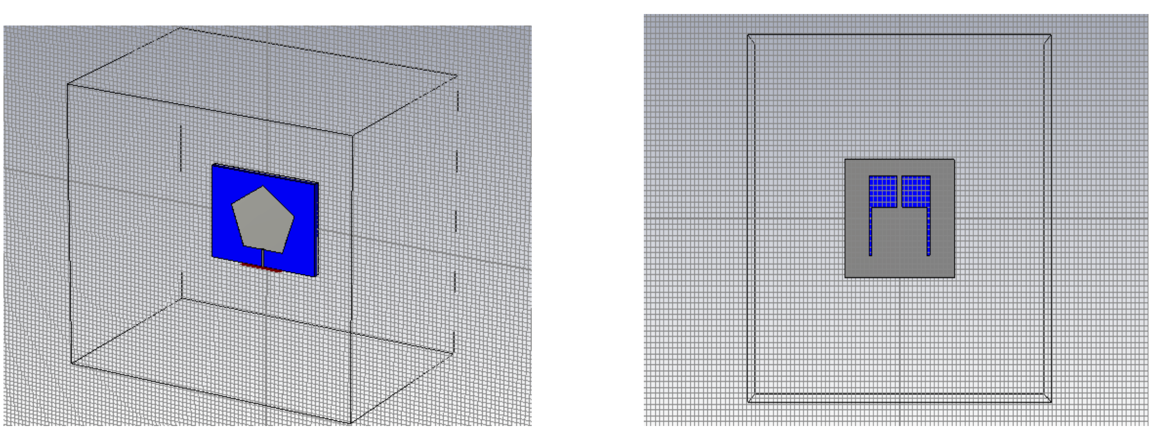
Table 5.1 Summarized results

Parameters	Band	Band
Resonating frequency	2.39GHz	5.79GHz
Gain	1.962dB	3.468dB
VSWR	1.2135	1.1225
BW	128MHz	105MHz

5.2 Dual band antenna design with DGS using microstrip line feed:

The geometry of microstrip line fed patch antenna with dual band operation for WLAN applications is depicted in figure 5.9. The pentagonal shaped patch is used and horse shoes slots are loaded in ground as shown below in designed antenna.

This is very simple structure to form dual band operation. The band covered by this design ie lower band at 4.28GHz and higher band is at 5.8GHz with proper impedance matching.



(a) (b)

Figure 5.9: Dual band antenna design (microstrip line feed) (a) Front view (b) Bottom view (DGS)

5.2.1 Return Loss:

From figure 5.10, it shows that the antenna resonates at 4.28GHz with bandwidth of 92dB and return loss is -42.14dB, And the higher band formed at 5.79GHz of bandwidth 101dB with return loss -26.95dB, as given below.

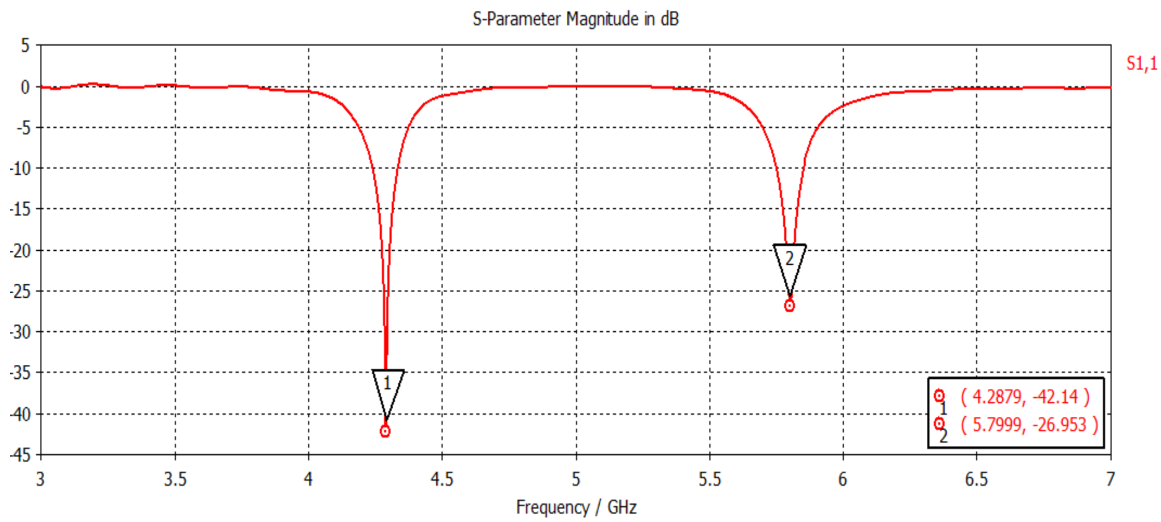


Figure 5.10: Simulated return loss [S11] at 4.28GHz and at 5.8GHz with return loss

5.2.2 Smith Chart

Figure 5.11 and shows the smith chart results at 50ohm impedance. From smith chart, it consists of two circles, one is at 4.28GHz with impedance of 50.81 ohm and another one is at 5.799GHz with 46.8ohm. Thus, frequencies are perfectly matched nearly at 50ohm.

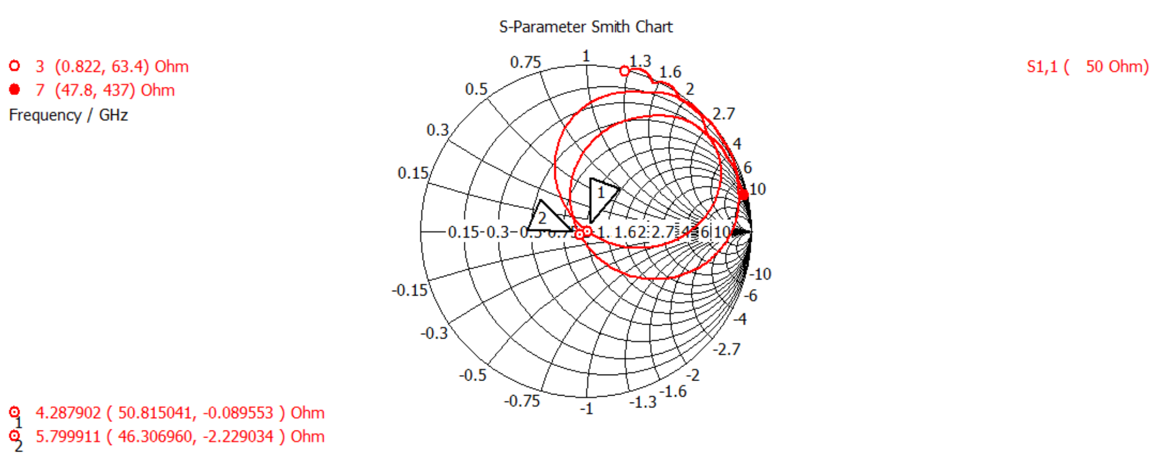


Figure 5.11: Smith chart

5.2.3 Radiation Pattern and Gain:

Figure 5.12 and 5.13 shows the radiation pattern plot for the proposed antenna with 4.547dB at 4.2GHz and 6.476dB gain at 5.8GHz frequency.

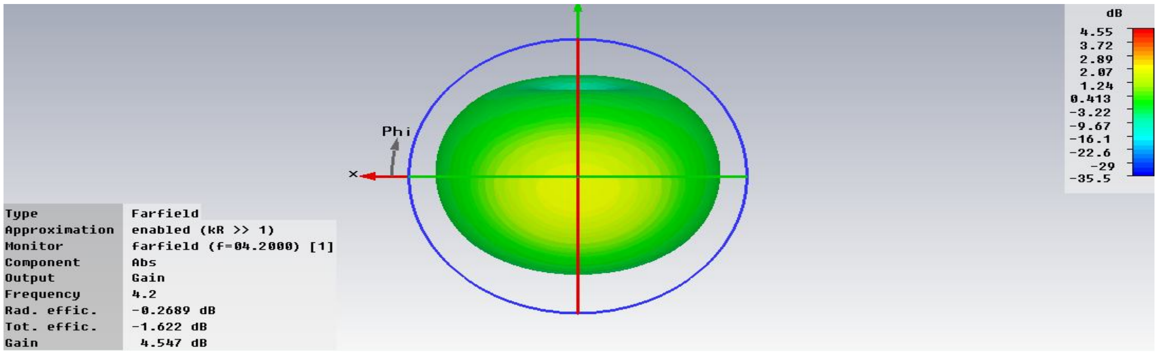


Figure 5.12: 3d Radiation pattern plot [4.28GHz]

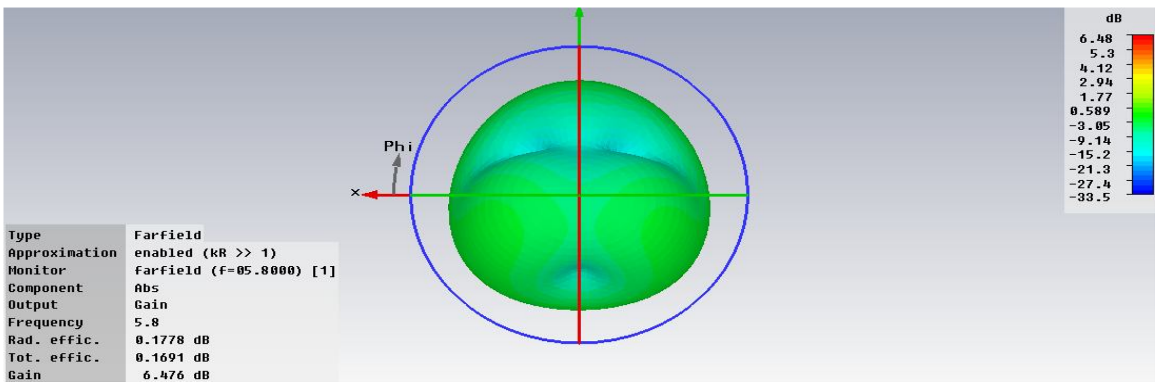


Figure 5.13: 3d-Radiation pattern plot [5.8GHz]

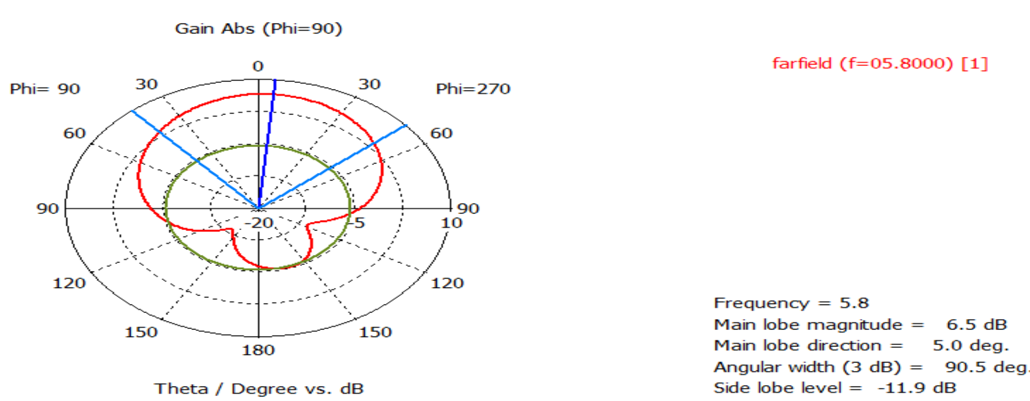
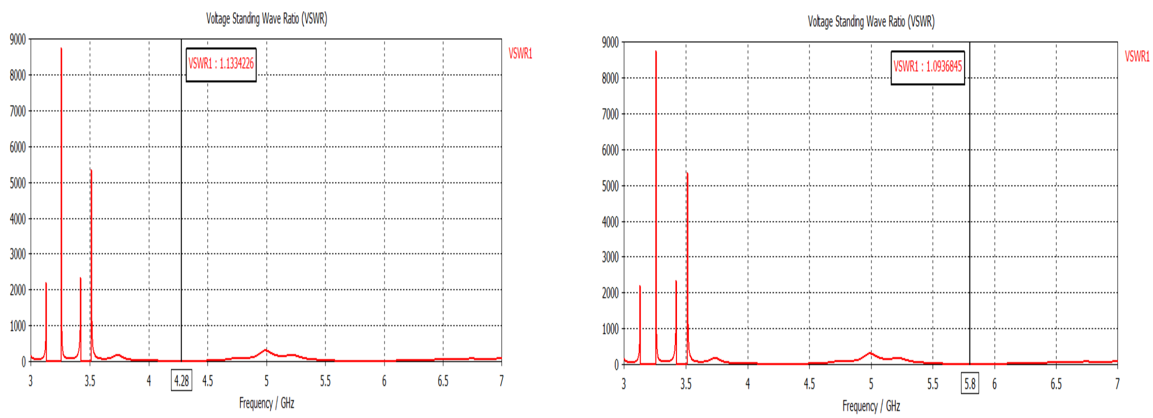


Figure 5.14: Polar-plot at 5.8GHz

The polar plot shows the lobes information in above, Figure 5.14, Polar-plot at 5.8GHz

5.2.4 VSWR:

The VSWR (voltage standing wave ratio) plot is shown in figure 5.15, for the designed antenna (microstrip line feed) at 4.28GHz, the value of VSWR is 1.1334 and at 5.8GHz VSWR = 1.0936. A VSWR of 1:1 means that there is no power being reflected back to the source, normally the VSWR of 1.2:1 (or simply 1.2) is considered excellent in most cases.



(a) (b)

Figure 5.15: VSWR-plot (a) 4.28GHz (b) 5.8GHz

Table 5.2 Summarized results

Parameters	Band	Band
Resonating frequency	4.28GHz	5.8GHz
Gain	4.547dB	6.476dB
VSWR	1.1947	1.0075
BW	92MHz	101MHz

Conclusion:

This chapter concludes the dual band antenna using defected ground structure using aperture and microstrip line feed.

Chapter 6

Fabrication of a Microstrip patch Antenna and comparison with Simulated Antenna

This chapter describes the simulated Antenna results of Return loss and entire procedure for fabrication of a microstrip patch antenna. Some fabricated antennas are also presented that are designed and simulated discussion is done in chapter 5.

6.1 Results of Single band microstrip antenna at 3.6GHz: The material used for designing an antenna and dimensions are given below:

Return Loss and BW:

The simulated value of return loss plot for the designed antenna with aperture feed is -50.29dB shown in figure 6.1 as below. The bandwidth is about 312MHz (3.763-3.451GHz). The designed antenna resonates at 3.6GHz.

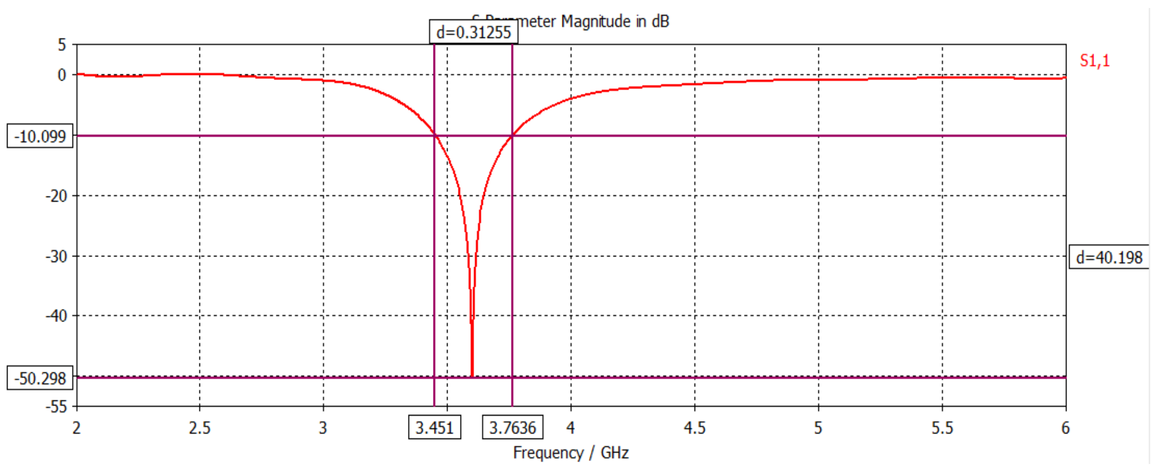


Figure 6.1: Simulated return loss [S11] at 3.6GHz

6.2 Result of Dual-band microstrip antenna at 3.6GHz and 5.29GHz:

The design resonating at two frequency bands namely 3.43-3.73GHz and 4.98-5.59GHz for WLAN/WiMAX applications.

From figure 6.2, it shows that the antenna covers a lower band of 3.437 to 3.735GHz of bandwidth 304dB with return loss -49.08dB and 4.98GHz to 5.59GHz with return loss of -14.43dB using simulated results.

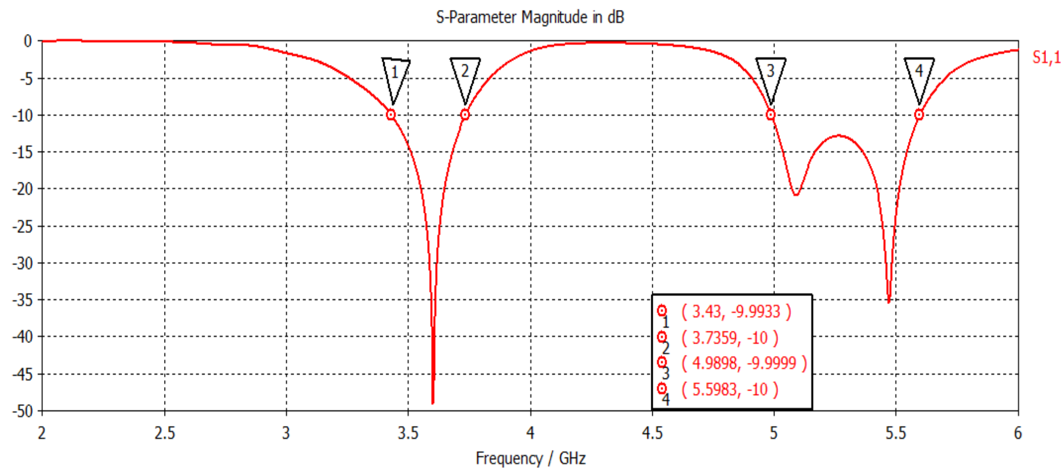
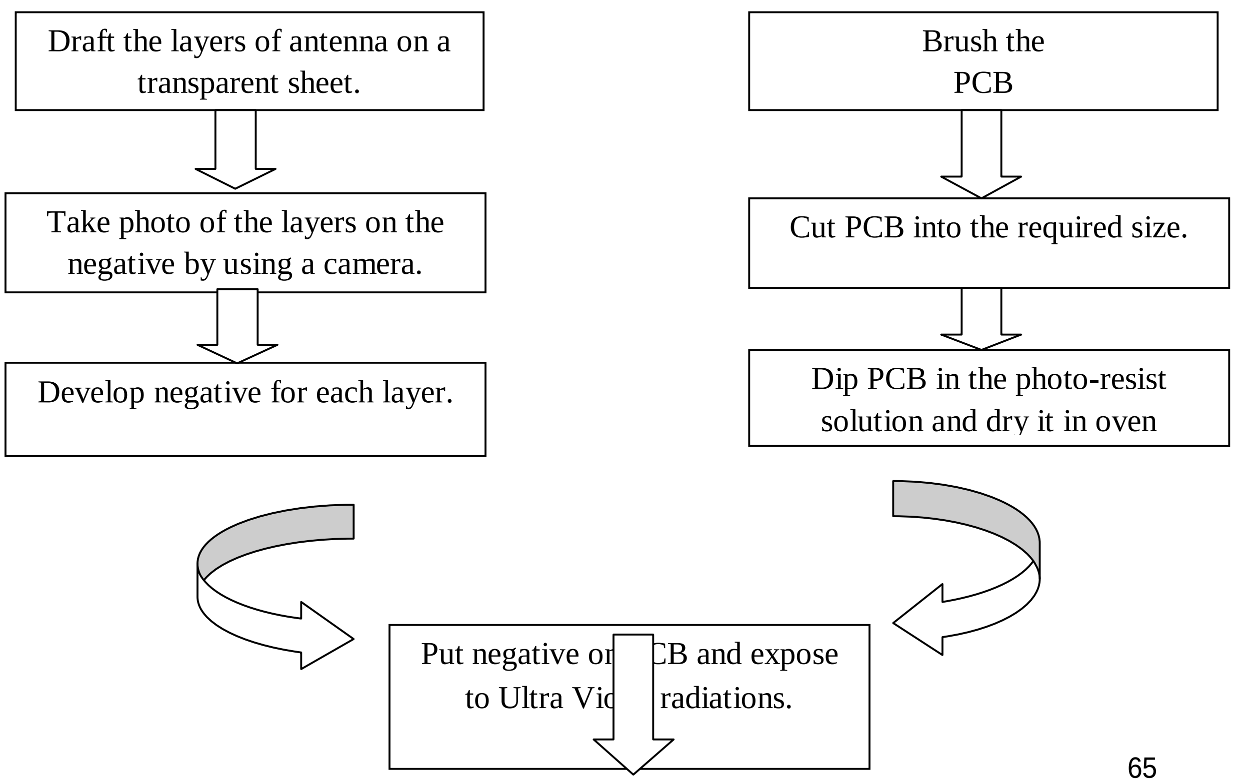


Figure 6.2: Simulated return loss [S11] at 3.6GHz

6.3 Fabrication process:

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



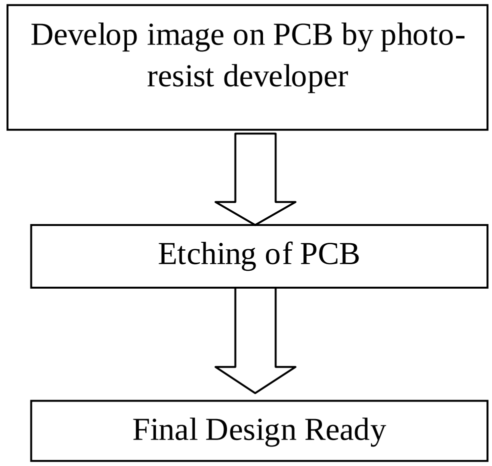


Figure 6.3: Fabricate Flow of PCB Design

6.4 Pictures of the instruments used while fabricating a microstrip Patch antenna:

The hardware used to design of the antenna includes two processes namely PCB (Printed circuit board) design and testing of the antenna. The various steps for the PCB design are explained as:

a) Negative developing: The negative development is done by software. The whole design in designed in this software and then print out of that design is taken.

b) The PCB cutter is used to PCB's as per desired size. The actual size of antenna i.e. Substrate size of material, like FR4 ($\varepsilon r = 4.4$) is used here. Figure 6.4 shows the PCB cutter.

Figure 6.4: PCB cutter

c) Operations on PCB: - Now the PCB is dipped once in the photo resist developer placed in yellow light. It dried in an oven for 3-5 minutes.

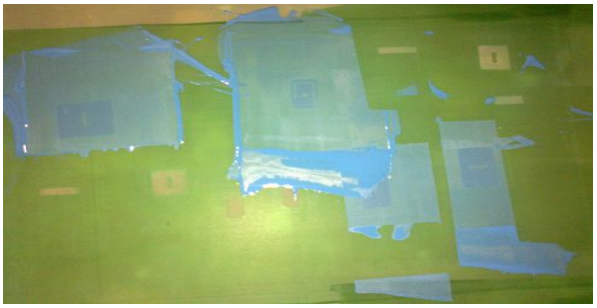


Figure6.5: PCB Coating Unit

The oven unit is used to dry the final design on antenna, which contain the paint on the layer that protects the copper to clean up. Thus, the oven dries the PCB at 140-150 degree temperature properly. Figure 6.6 shows the picture of the Oven Unit.

Figure6.6: Oven Unit

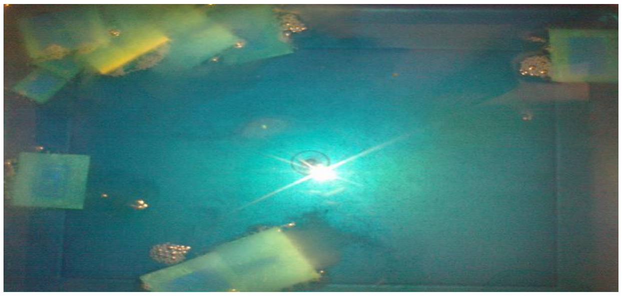
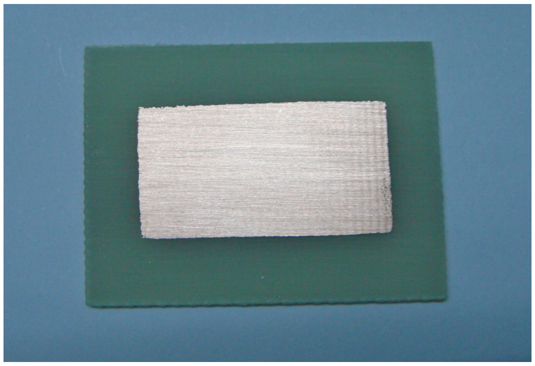


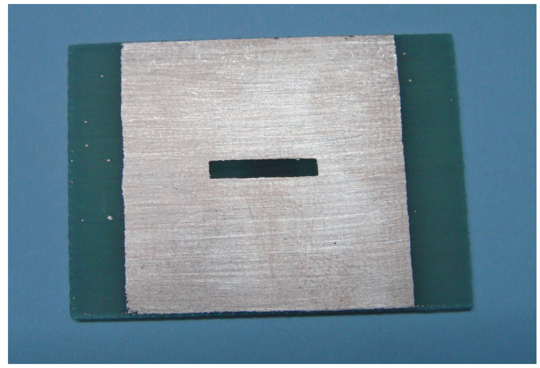
Figure 6.7: Etching Unit

6.5 Fabricated microstrip patch antenna for Single and Dual bands:

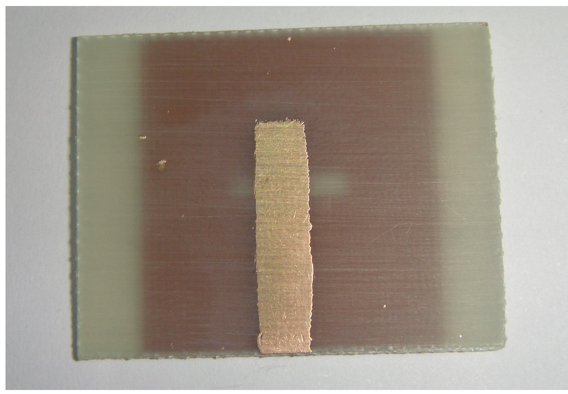
Below are the some fabricated antennas. Figure shows the simple single band antenna at 3.6GHz with reduced ground structure to increase the bandwidth. Figure 6.8 shows the G-shaped antenna with reduced ground structure to increase the bandwidth and to get dual band i.e. at 3.6GHz and 5.29GHz. And both are the fabricated microstrip antennas with aperture feed. The simulated results for both the antennas are discussed in chapter 3 and chapter 4.



(a) Top view of patch



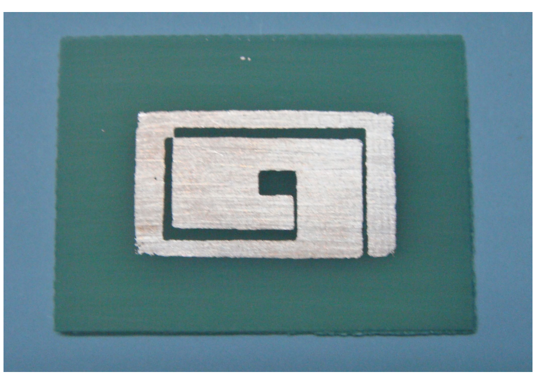
(b) View of ground



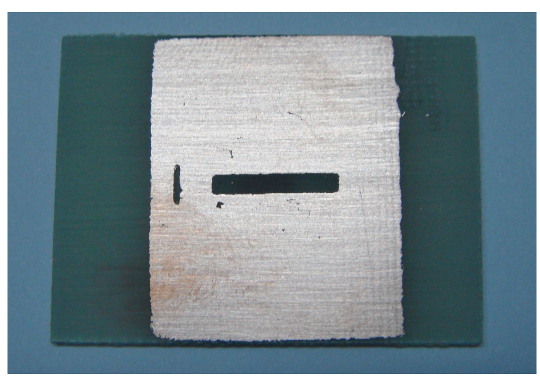
(c) View of aperture feed

Figure 6.8: Fabricated antenna with aperture feed (Single band) (a) (b) (c) views

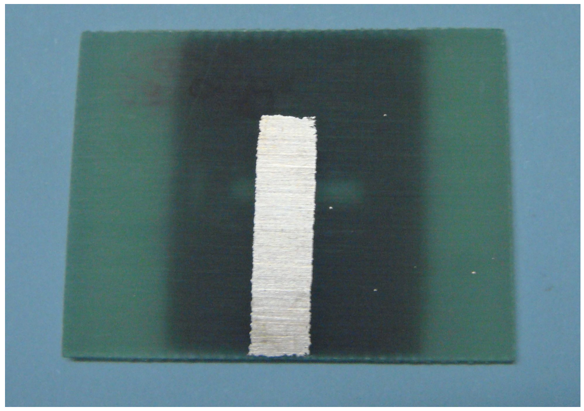
As from these figures, the material used for fabrication antenna is PEC (Copper) of height 0.035mm with 1.6mm (Substrate) thus, the total height of antenna is 3.305mm formed.



(a) Top view of patch



(b) View of ground



(c) View of aperture feed

Figure 6.9: Fabricated antenna with aperture feed (dual band) (a) (b) (c)

6.6 Results of Testing On VNA:

An aperture coupled single band microstrip patch antenna at 3.6GHz for WiMAX application was designed using CST2010 studio (software). But practically, antenna has been tested using VNA (9KHz-8.5GHz) shown below:

Figure 6.10: Instrument used for testing

By testing results using VNA, it is clear from the snapshot that the antenna resonates at 3.588GHz frequency and covers the range from 3.4GHz to 3.812GHz. Thus bandwidth formed is (3.812-3.4) 412GHz i.e. wide band covered by antenna, useful for WiMAX application. Figure 6.11 shows the graph at 3.58GHz.

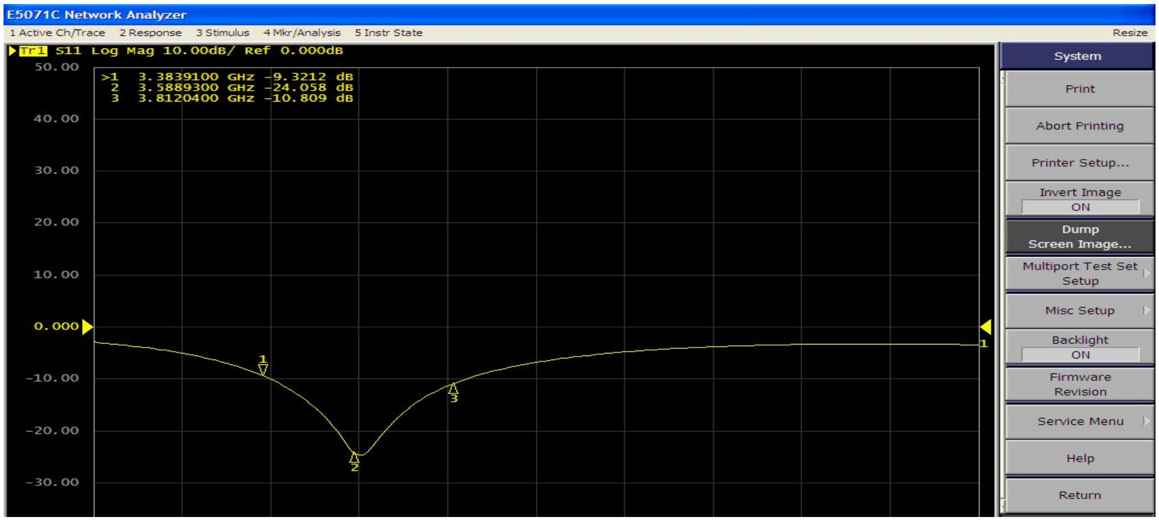


Figure 6.11: Testing Results at 3.6GHz

By testing it resonates at 3.584GHz and covers the band from 3.669GHz- 3.506GHz i.e. 163MHz bandwidth and return loss at this frequency is -34.3dB. Another frequency resonates at 5.5GHz (5.767-5.339) and gives 428MHz bandwidth with return loss of -27.917dB as shown in figure 6.12 shows the graph.

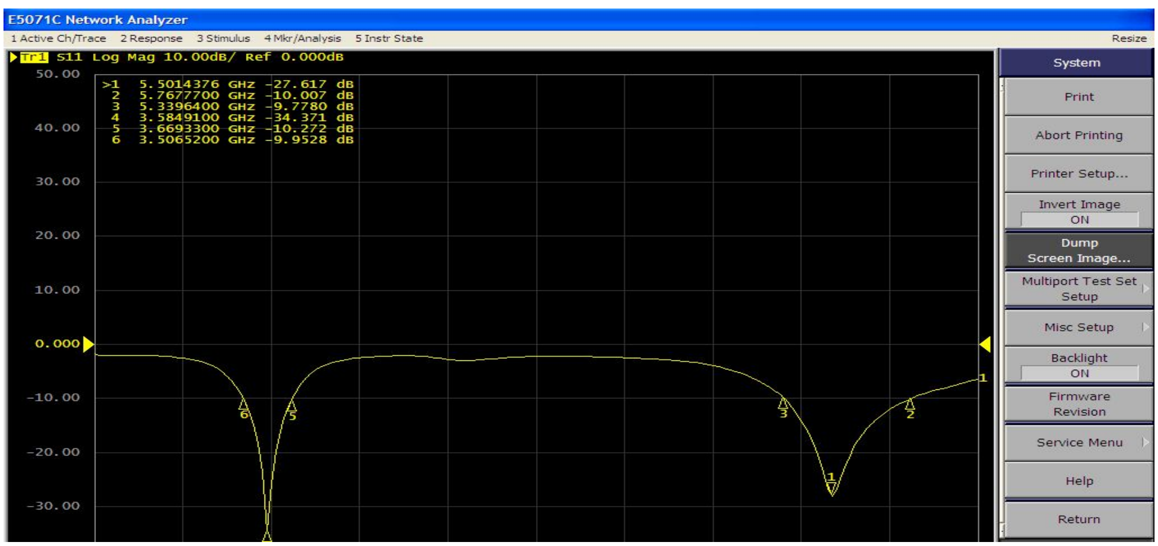


Figure 6.12: Testing results at 3.58 and 5.5GHz

In the single band, the simulated result resonates at 3.6GHz and in the fabricated results; antenna shifts to left and resonates at 3.588GHz. In the dual band, the simulated results covers the frequency bands 3.6GHz and 5.29GHz and in the fabricated results, antenna shifts to the right and covers the frequency bands 3.6GHz and 5.5GHz.

The return loss graphs show that the resonant frequencies have shifted in the magnitude from the designed frequency for dual band antenna and reduce the BW. The root cause of the shift is could be due to the FR-4 board, which has that varies from 4.0 to 4.9. In practical world, a material which has varying along a length, width, and height, will affect resonant frequency to shift, during simulation it is assume a constant. The other factors affecting etching accuracy such as chemical used, surface finish and metallization thickness also could be the reason for shifting the resonant frequency.

The variation on the return loss, resonant frequency and bandwidth, from the simulation software constraint. In simulation, the design is ideal and no air gap exists between the patch and the ground plane. Practically, with the use of adhesive to glue the patch to the ground plane, the variation is more visible as the adhesive will affect the effective dielectric constant value and contribute some height to the gap. Other than that, electromagnetic coupling is also one of the important mechanisms in aperture coupled microstrip antenna. But the in the simulation, the electromagnetic coupling to the environment is not modeled. One major reason of reduced BW is the connector used to give supply, the available connector is small as compared to port applied for giving supple the antenna.

6.6.1 Comparison of Simulated results and fabricated results:

Table 6.1 Comparison between Simulated results and Fabricated results

Parameters	**Simulated Results**	**Fabricated Results**
Frequencies Covered in Single band	3.6GHz	3.588GHz
Frequencies Covered in Dual band	3.6 GHz and 4.9 GHz to 5.6 GHz	3.588 GHz and 5.3GHz to 5.798 GHz
Return Loss of single band	-50.29	-24.058
Return Loss of dual band	-49 dB (at 3.6GHz)	-34.3 dB (at 3.6 GHz)

	-14 dB (at 5.29 GHz)	-27.91 dB (at 5.5GHz)
Bandwidth of single band	312MHz	412MHz
Bandwidth of Dual band	305MHz (at 3.6GHz) 614 MHz (at 5.29 GHz)	163 MHz (at 3.6GHz) 428 MHz (at 5.29 GHz)
Applications covered by single band	WiMAX	WiMAX
Applications covered by Dual band	WiMAX (at 3.6GHz) WLAN (4.9GHz – 5.6 GHz)	WiMAX (at 3.6GHz) Wi-Fi (at 5.3 GHz – 5.79 GHz)

Conclusion

This chapter concludes that, the fabrication of an antenna for single and dual band with testing is done and comparison between single band and dual band with simulated and tested results is performed. From observation, there occurs some shifts in the results of fabricated dual band antenna with reduced BW due to some non-linearity's.

Chapter 7

Conclusion and Future Scope

7.1 Conclusion

As from the first chapter of Thesis, it is observed that because of various advantages of microstrip patch antenna it can be used in various applications. The aperture coupling feeding technique for the microstrip patch antenna has been studied, that is used for both WLAN and WiMAX applications.

The second chapter concludes the literature survey for aperture coupling and microstrip line feeding techniques has been studied.

The third chapter presents a microstrip patch antennas for a single frequency 3.6GHz and 5.2GHz with aperture coupling feeding technique is presented that provides a bandwidth of 285 MHz and 312MHz, hence, this antenna can be used for the WLAN/WiMAX applications. The various parameters like patch size, gain, directivity and bandwidth etc. have been studied and compared. The comparison using different patch shapes at 5.8GHz is formed. The maximum gain is obtained using pentagonal shape with more BW.

The fourth chapter presents microstrip antenna can be fed by aperture coupled feeding technique with reduced ground structure for wide and dual band operation, it covers two bands of resonating frequencies at 3.6GHz and 5.29GHz, and range of bands is from 3.4301GHz-3.7354GHz (BW = 3.5MHz) and another range is from 4.9917GHz-5.5967GHz (BW = 605MHz). Return loss is obtained maximum at 3.6GHz i.e. -49dB and minimum RL at 5.29GHz i.e. -13.01dB respectively. The comparison for both antennas in terms of gain, directivity, E-field and H-field is listed in the Table 4.1

Table 7.1 Comparison between single and dual band

Parameters	**Single band**	**Dual band**	
Frequency(GHz)	3.6	3.6	5.29

Directivity (dBi)	4.381	3.892	3.954
Gain (dB)	4.670	4.388	4.389
E-field (dBV/m)	19.43	19.15	18.92
E-field(dBW/m2)	-32.09	-32.37	-32.60

Parameter sweep results shows (Refer chapter4) that, as slot length changes it effects the resonating frequency and return loss. The sweep results on slot length and width shows the change in frequency and BW, similarly in case of stub length and width of feed the main affect formed in return loss and frequency.

In fifth chapter, it concludes that the DGS structure is used to design single to dual band operation with single antenna. With H-shaped ground, design covers 2.5GHz and 5.8GHz using aperture feed and with horse shoe slot in ground, cover 4.28GHz and 5.79GHz for WLAN application.

Table 7.2 Summarized results

Parameters	**Band**	**Band**
Resonating frequency	2.39GHz	5.79GHz
Gain	1.962dB	3.468dB
VSWR	1.2135	1.1225
BW	128MHz	105MHz

Table 7.3 Summarized results

Parameters	**Band**	**Band**
Resonating frequency	4.28GHz	5.8GHz
Gain	4.547dB	6.476dB
VSWR	1.1947	1.0075
BW	92MHz	101MHz

The sixth chapter gives the fabrication of an antenna for single and dual band with testing is done and comparison between single band and dual band with simulated and tested results is performed. From observation, there is occurs some shifts in the results of fabricated dual band antenna with reduced BW due to some non-linearity's. The simulated result resonates at 3.6GHz and in the fabricated results; antenna shifts to left and resonates at 3.588GHz. In the dual band, the simulated results covers the frequency bands 3.6GHz and 5.29GHz and in the fabricated results, antenna shifts to the right and covers the frequency bands 3.6GHz and 5.5GHz.

7.2 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 wideband for different applications like WLAN/WiMAX using aperture coupling 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. Next, the work on the miniaturization of the microstrip antennas and to get large bandwidth through CPW can be carried out.
The research work could be extended to

- Multiband of the antenna for various wireless applications by stacking, different shaped in patch, DGS(with stacking)
- Array designing to enhance the gain and other antenna properties.
- Optimization of the antenna using Genetic algorithm, Neural network
- The other feeding techniques of microstrip patch antenna like microstrip line, coaxial feeding, aperture coupling and CPW can also be used in future to design microstrip patch antenna for wideband and multiband antennas.

- Electromagnetic Band Gap (EBG) substrates for patch antennas significantly reduce the effect of surface waves as a function of frequency and are able to provide relatively broadband frequency performance.

List of Publications

- Manpreet Kaur, Amanpreet kaur, Dr. Rajesh Khanna, "A Microstrip Patch Antenna with Aperture Coupler Technique at 5.8 GHz & 2GHz" , MIT Research & Conference, June 2012.

- Manpreet Kaur, Amanpreet kaur, "Micro-strip Antennas for Wireless Applications at 5.8GHz using Different Shapes of Patch", ID-ICCE-2012-23, July 2012.

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