Dual Band and Dual Polarized Microstrip Patch Antenna

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by

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Certificate

This is to certify that the work in the thesis entitled ***Dual Band and Dual Polarized Microstrip Patch Antenna*** by Soumya Ranjan Behera & Vishnu V, is a record of an original research work carried out by them under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electronics and Communication engineering at the National Institute of Technology, Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Prof. S. K. Behera

Associate Professor

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Abstract

In today's modern communication industry, antennas are the most important components required to create a communication link. Microstrip antennas are the most suited for aerospace and mobile applications because of their low profile, light weight and low power handling capacity. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth, dual band and circular polarization to even ultra wideband operation. The thesis provides a detailed study of the design of probe-fed Rectangular Microstrip Patch Antenna to facilitate dual polarized, dual band operation. The design parameters of the antenna have been calculated using the transmission line model and the cavity model. For the simulation process IE3D electromagnetic software which is based on method of moment (MOM) has been used. The effect of antenna dimensions and substrate parameters on the performance of antenna have been discussed.

The antenna has been designed with embedded spur lines and integrated reactive loading for dual band operation with better impedance matching. The designed antenna can be operated at two frequency band with center frequencies 7.62 (with a bandwidth of 11.68%) and 9.37 GHz (with a bandwidth of 9.83%). A cross slot of unequal length has been inserted so as to have dual polarization. This results in a minor shift in the central frequencies of the two bands to 7.81 and 9.28 GHz. At a frequency of 9.16 GHz, circular polarization has been obtained. So the dual band and dual frequency operation has successfully incorporated into a single patch.

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Chapter 1

Introduction and Overview

1.1 Introduction

Many wireless service providers have discussed the adoption of polarization diversity and frequency diversity schemes in place of space diversity approach to take advantage of the limited frequency spectra available for communication. Due to the rapid development in the field of satellite and wireless communication there has been a great demand for low cost minimal weight, compact low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies. Through the years, microstrip antenna structures are the most common option used to realize millimeter wave monolithic integrated circuits for microwave, radar and communication purposes. Compact microstrip antennas capable of dual polarized radiation are very suitable for applications in wireless communication systems that demand frequency reuse and polarization diversity.

1.2 Aim and Objective

The aim of the project is to design and fabricate a dual frequency and dual polarized microstrip patch antenna. This tutorial provides an in-depth explanation of antenna pattern measurement techniques used to determine the performance of dual polarized antennas and of some antenna characteristics that are unique to antennas used in a polarization diversity scheme. The performance comparison is based on radiation pattern, bandwidth, return loss, vswr and gain. The slit length, slit width, distance of the slit from the edge of the patch, feed point and the cross slot parameters are varied in order to obtain optimum results.

1.3 Motivation

Use of conventional microstrip antennas is limited because of their poor gain, low bandwidth and polarization purity. There has been a lot of research in the past decade in this area. These techniques include use of cross slots and sorting pins, increasing the thickness of the patch, use of circular and triangular patches with proper slits and antenna arrays. Various feeding techniques are also extensively studied to overcome these limitations. Our work was primarily focused on dual band and dual frequency operation of microstrip patch antennas. Dual frequency operation of the antenna has become a necessity for many applications in recent wireless communication systems. Antennas having dual polarization can be used to obtain polarization diversity.

1.4 Outline of the Thesis

The outline of this thesis is as follows

Chapter 2 presents the basic theory of MPAs, including the basic structures, feeding techniques and characteristics of the MPA. Then the advantages and disadvantages of the antenna are discussed and the methods of analysis used for the MPA design. Finally the performance parameters to compare the various antenna structures have been discussed. The calculations needed to find the dimensions of the conventional MPA using transmission line model are presented in this chapter.

Chapter 3 outlines the various methods to obtain dual band and dual polarization in compact MPAs are discussed. Gain and bandwidth enhancement techniques are also discussed in brief.

Chapter 4 discusses in detail the patch proposed for dual band dual frequency application. The simulation results for this antenna has been discussed.. Then the performance of the antenna has been studied by comparing return loss, radiation pattern, VSWR, gain, bandwidth and axial ratio.

Chapter 5 presents the concluding remarks, with scope for further research work.

Chapter 2

Microstrip Antenna

2.1 General structure of Microstrip Patch Antenna

A microstrip antenna generally consists of a dielectric substrate sandwiched between a radiating patch on the top and a ground plane on the other side as shown in Figure 2.1. 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.

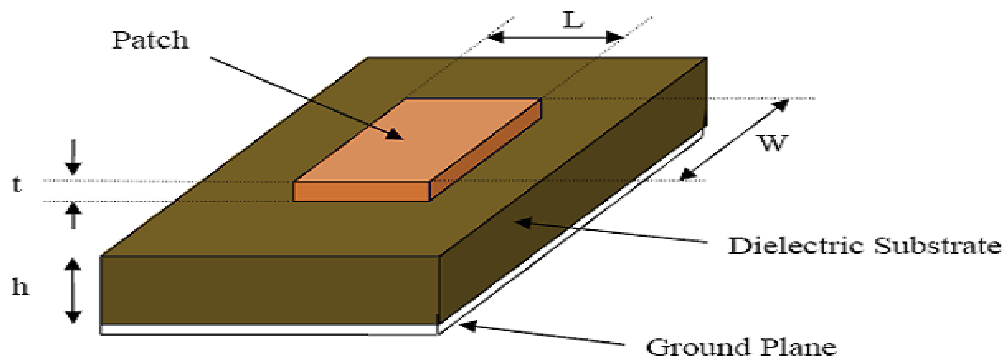


Figure 2.1 Structure of a Microstrip Patch Antenna

For simplicity of analysis, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape. For a rectangular patch, the length L of the patch is usually in the range of $0.3333\,\lambda_0 < L < 0.5\,\lambda_0$, where λ_0 is the free space wavelength. The patch is selected to be very thin such that $t << \lambda_0$ (where t is the patch thickness). The height h of the substrate is usually$0.003\,\lambda_0 \leq h \leq 0.05\,\lambda_0$. The dielectric constant of the substrate ϵr is typically in the range $2.2 \leq \epsilon r \leq 12$ [3].

2.2 Advantages and Disadvantages

Microstrip antennas are used as embedded antennas in handheld wireless devices such as cellular phones, and also employed in Satellite communications. Some of their principal advantages are given below:

- Light weight and low fabrication cost.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits.
- 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 and Gain.
- Extraneous radiation from feeds and junctions.
- Low power handling capacity.
- Surface wave excitation.

2.3 Feed Techniques

Microstrip patch antennas can be fed by a variety of methods. These methods 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 four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

2.3.1 Microstrip (Offset 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 2.2. The conducting strip is smaller in width as compared to the patch. This kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.

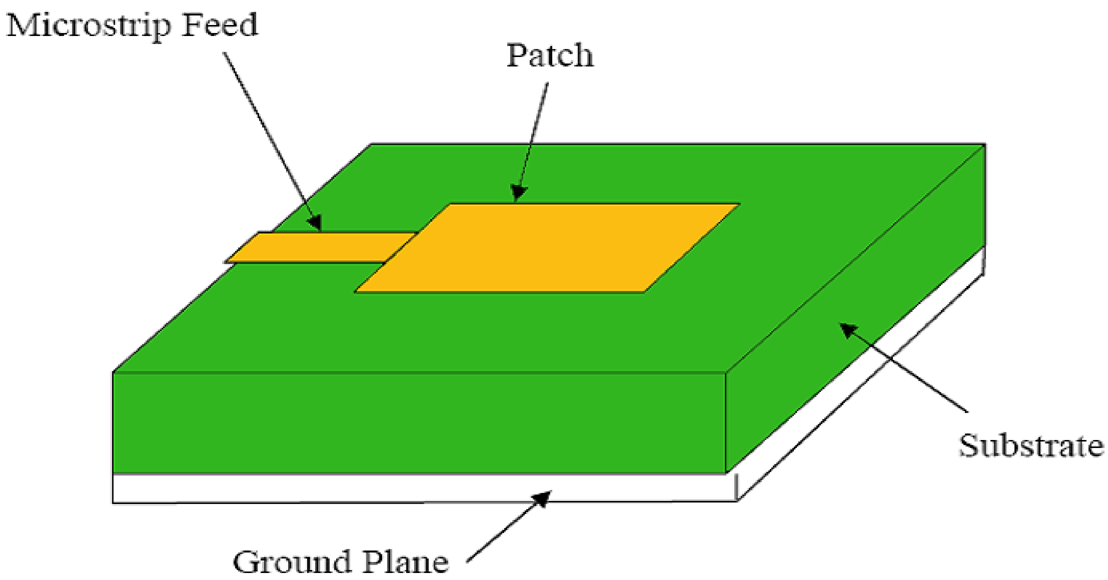


Figure 2.2 Microstrip Line Feed

An inset cut can be incorporated into the patch in order to obtain good impedance matching without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding technique, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. However as the thickness of the dielectric substrate increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. This type of feeding technique results in undesirable cross polarization effects.

2.3.2 Coaxial Feed

The Coaxial feed or probe feed is one of the most common techniques used for feeding microstrip patch antennas. As seen from figure 2.3, 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.

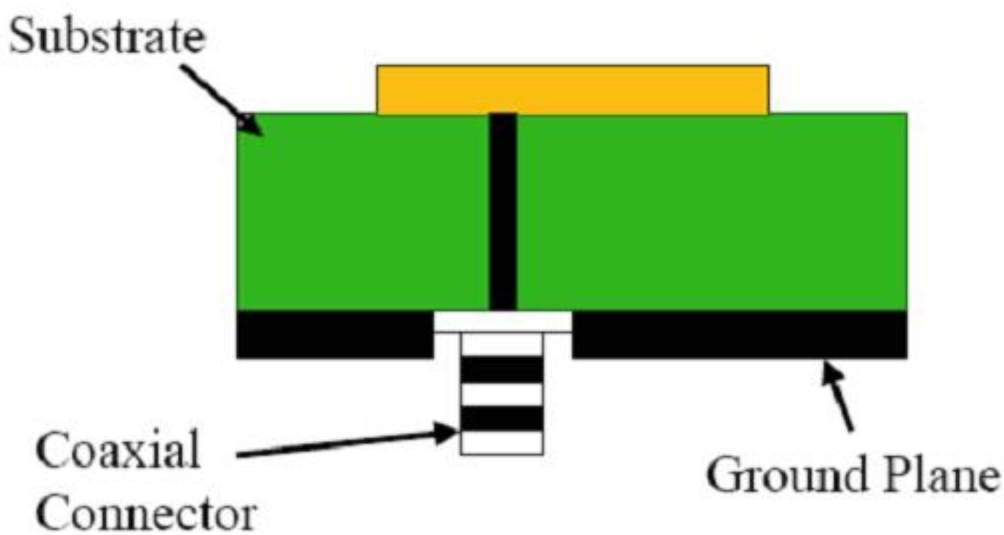


Figure 2.3 Coaxial feed

The main advantage of this type of feeding scheme is that the feed can be placed at any desired position inside the patch in order to obtain impedance matching. This feed method is easy to fabricate and has low spurious radiation effects. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled into the substrate. Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems.

By using a thick dielectric substrate to improve the bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages such as spurious feed radiation and matching problem. The non-contacting feed techniques which have been discussed below, solve these problems.

2.3.3 Aperture Coupled Feed

In aperture coupling as shown in figure 2.4 the radiating microstrip patch element is etched on the top of the antenna substrate, and the microstrip feed line is etched on the bottom of the feed substrate in order to obtain aperture coupling. The thickness and dielectric constants of these two substrates may thus be chosen independently to optimize the distinct electrical functions of radiation and circuitry. 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

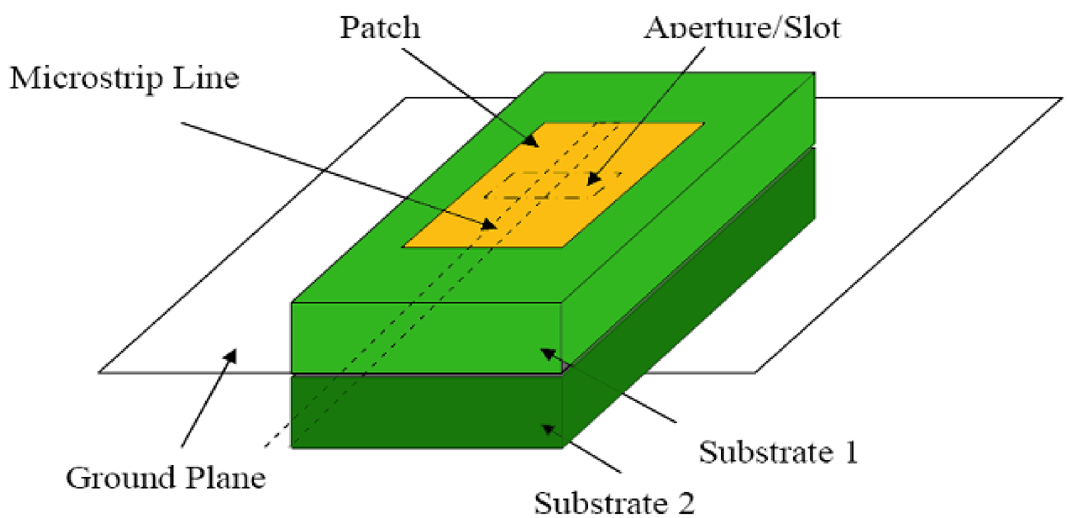


Figure 2.4 Aperture coupled feed

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. This type of feeding technique can give very high bandwidth of about 21%. Also the effect of spurious radiation is very less as compared to other feed techniques. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness.

2.3.4 Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in figure 2.5, 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 of about 13%, due to increase in the electrical thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

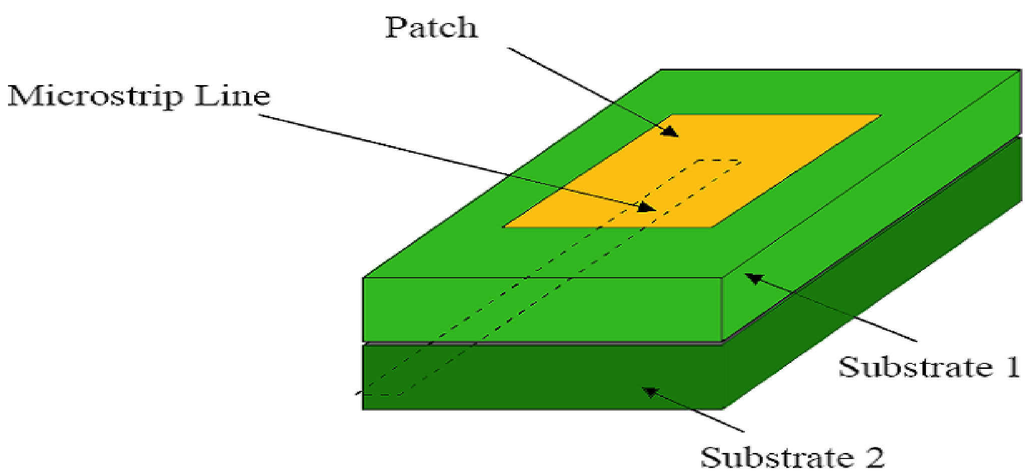


Figure 2.5 Proximity coupled feed

The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers that need proper alignment. Also, there is an increase in the overall thickness of the antenna.

2.4 Methods 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. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

Since the design of microstrip antenna in this thesis is based on the Transmission Line Model and Cavity model, the discussion is limited to this.

2.4.1 Transmission Line Model

This model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a non homogeneous line of two dielectrics, typically the substrate and air.

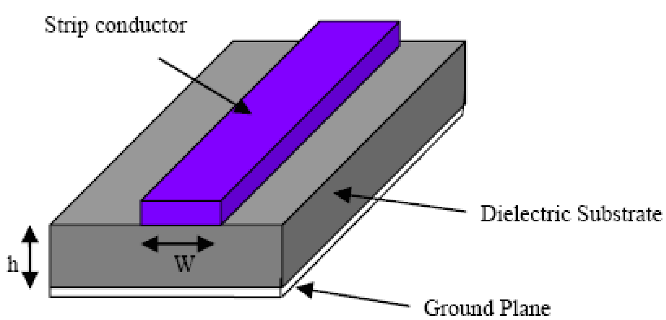


Figure 2.6(a) Microstrip Line

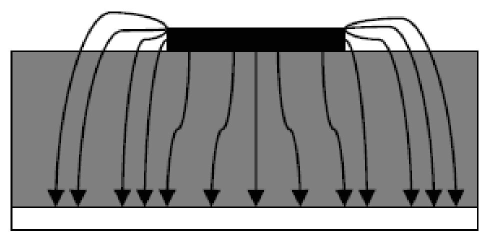


Figure 2.6(b) Electric Field Lines

Hence, as seen from Figure 2.6(b), most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant ($\varepsilon reff$) must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\varepsilon reff$ is slightly less then εr because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in air.

The expression for $\varepsilon reff$ is given by [1] as:

$$\varepsilon \text{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}},$$

where $\varepsilon reff = Effective\ dielectric\ constant$

$\varepsilon r = Dielectric\ constant\ of\ substrate$

$h = Height\ of\ dielectric\ substrate$

$W = Width\ of\ the\ patch$

In the Figure 2.7(a) shown below, the microstrip patch antenna is represented by two slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is a maximum and the current is a minimum due to open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

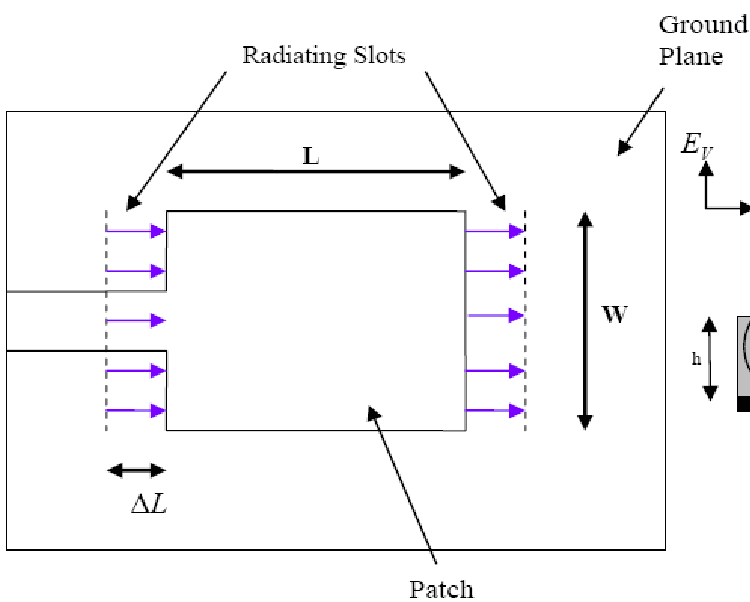


Figure 2.7(a) Top View of Antenna

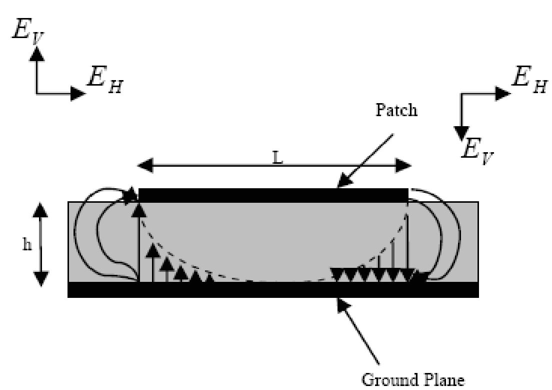


Figure 2.7(b) Side View of Antenna

It is seen from Figure 2.7(b) that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is $\lambda/2$ long and hence they cancel each other in the broadside direction. The edges along the width can be represented as two radiating slots, which are $\lambda/2$ apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically by [1] as:

$$\Delta L = 0.412h \, \frac{(\mathcal{E}\text{reff} + 0.3)(\frac{w}{h} + o.264)}{(\mathcal{E}\text{reff} - 0.258)(\frac{w}{h} + o.8)}.$$

The effective length of the patch $Leff$ now becomes

$$Leff = \frac{C}{2f0\sqrt{\mathcal{E}\text{reff}}}$$

For a given resonant frequency f0, the effective length is given by

$$Leff = L + 2\Delta L.$$

For a rectangular microstrip patch antenna, the resonant frequency for any TM mode is given by [1] as:

$$fo = \frac{C}{2\sqrt{\mathcal{E}\text{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}},$$

$where\ m\ and\ n\ are\ modes\ along\ L\ and\ W\ respectively.$

For effective radiation, the width W is given by [3] as:

$$W = \frac{C}{2f0\sqrt{\frac{\mathcal{E}r+1}{2}}}.$$

2.4.2. Cavity Model

The cavity model helps to give insight into the radiation mechanism of an antenna, since it provides a mathematical solution for the electric and magnetic fields of a microstrip antenna. It does so by using a dielectrically loaded cavity to represent the antenna. This technique models the substrate material, but it assumes that the material is truncated at the edges of the patch. The patch and ground plane are represented with perfect electric conductors and the edges of the substrate are modeled with perfectly conducting magnetic walls.

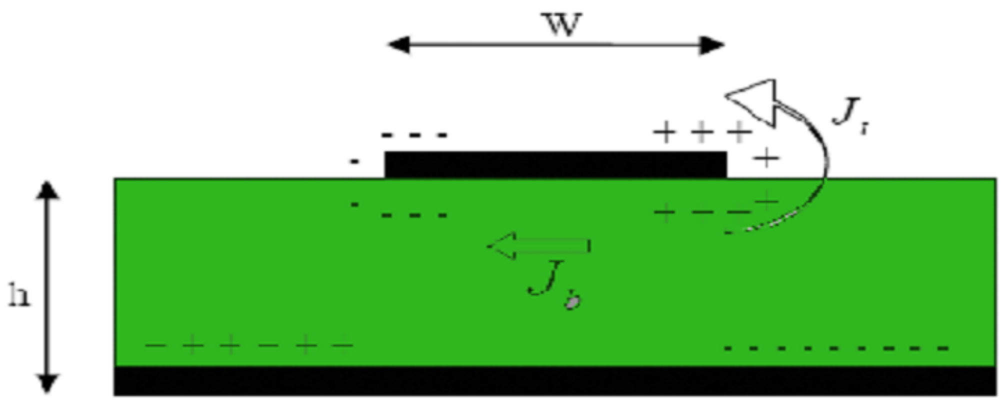


Figure 2.8 Charge distribution and current density creation on the microstrip patch

Consider Figure 2.8 shown above. When the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms ─ an attractive mechanism and a repulsive mechanism. The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces. Therefore, we only need to consider TMz modes inside the cavity. Now, we can write an expression for the electric and magnetic fields within the cavity in terms of the vector potential Az [2]:

$$\mathrm{E_x} = -j\frac{1}{\mu\omega\mathcal{E}}\frac{\partial^2 \mathrm{A_z}}{\partial_\mathrm{x}\,\partial_\mathrm{y}} \qquad H_x = \frac{1}{\mu}\frac{\partial A_z}{\partial y},$$

$$\mathrm{E_y} = -j\frac{1}{\mu\omega\mathcal{E}}\frac{\partial^2 \mathrm{A_z}}{\partial_\mathrm{y}\,\partial_\mathrm{z}} \qquad H_y = \frac{1}{\mu}\frac{\partial A_z}{\partial x},$$

$$E_z = -j\frac{1}{\mu\omega\mathcal{E}}\left(\frac{\partial^2}{\partial z^2} + K^2\right)A_z \qquad H_z = 0\,.$$

Since the vector potential must satisfy the homogeneous wave equation, we can use separation of variables to write the following general solution.
Hence we obtain a solution for the electric and magnetic fields inside the cavity as given below.

$$E_x = -j\frac{K_x\ K_y}{\mu\omega\mathcal{E}}A_{mnp}\ \sin(K_x\ x)\ \cos(K_y\ y)\sin(K_z\ z)\,,$$

$$E_y = -j\frac{K_y\ K_z}{\mu\omega\mathcal{E}}A_{mnp}\ \cos(K_x\ x)\sin(K_y\ y)\ \sin(K_z\ z)\,,$$

$$E_x = -j\frac{K^2-K_z^2}{\mu\omega\mathcal{E}}A_{mnp}\ \cos(K_x\ x)\cos(K_y\ y)\cos(K_z\ z),$$

$$H_x = -\frac{K_y}{\mu}A_{mnp}\cos(K_x\ x)\sin(K_y\ y)\ \cos(K_z\ z),$$

$$H_y = -\frac{K_x}{\mu}A_{mnp}\sin(K_x\ x)\ \cos(K_y\ y)\cos(K_z\ z),$$

$$H_z = 0.$$

Here

$$K_x = \frac{m\Pi}{L}, m = 0,1,2 \ldots\ldots\ldots$$

$$K_y = \frac{n\Pi}{W}, n = 0,1,2 \ldots\ldots\ldots\ldots$$

$$K_z = \frac{p\Pi}{h}, p = 0,1,2 \ldots\ldots\ldots\ldots$$

where $m = n = p \neq 0$ and A_{mnp} is the amplitude coefficient.

The resonant frequency for the cavity is given by

$$(fr)mnp = \frac{1}{2\Pi\sqrt{\mu\mathcal{E}}}\left[\left(\frac{m\Pi}{L}\right)^2 + \left(\frac{n\Pi}{W}\right)^2 + \left(\frac{p\Pi}{h}\right)^2\right]^{\frac{1}{2}}$$

2.5 Performance Parameters

The performance of an antenna can be measured by a number of parameters. The followings are the critical ones.

(a) Radiation Pattern

The antenna pattern is a graphical representation in three dimensional of the radiation of the antenna as the function of direction. It is a plot of the power radiated from an antenna per unit solid angle which gives the intensity of radiations from the antenna [3]. If the total power radiated by the isotropic antenna is P, then the power is spread over a sphere of radius r, so that the power density S at this distance in any direction is given as:

$$S = \frac{P}{4\pi r^2}$$

Then the radiation intensity for this isotropic antenna Ui can be written as:

$$Ui = \frac{P}{4\pi}$$

Isotropic antennas are not realizable in practice but can be used as a reference to compare the performance of practical antennas. The radiation pattern provides information on the antenna beam width, side lobes and antenna resolution to a large extent.

The E plane pattern is a graphical representation of antenna radiation as a function of direction in a plane containing a radius vector from the centre of the antenna to the point of maximum radiation and the electric field intensity vector. Similarly the H plane pattern can be drawn considering the magnetic field intensity vector

.

(b) Gain

Antenna gain is the ratio of maximum radiation intensity at the peak of main beam to the radiation intensity in the same direction which would be produced by an isotropic radiator having the same input power. Isotropic antenna is considered to have a gain of unity. The gain function can be described as:

$G(\theta, \emptyset) = \frac{P(\theta,\emptyset)}{\frac{Wt}{4\pi}}$, where$P(\theta, \emptyset)$ is the power radiated per unit solid angle in the direction$(\theta, \emptyset)$ and Wt is the total radiated power.

Microstrip antennas because of the poor radiation efficiency have poor gain. Numerous researches have been conducted in various parts of the world in order to obtain high gain antennas.

(c) Directivity

If a three dimensional antenna pattern is measured, the ratio of normalized power density at the peak of the main beam to the average power density is called the directivity.

The directivity of the antenna is given by:

$$D = \frac{Pmax}{Pav}$$

The relation between directivity and gain can be given as:

$G = \eta D$, where η is the antenna efficiency.

(d) Bandwidth

It is defined as "The range of usable frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." The bandwidth can be the range of frequencies on either side of the center frequency where the antenna characteristics like input impedance, radiation pattern, beam width, polarization, side lobe level or gain, are close to those values which have been obtained at the center frequency. The bandwidth of narrow band and broadband antennas are defined as:

$$BWbroadband = \frac{Fh}{Fl}$$

$$BWnarrowband(\%) = \frac{Fh-Fl}{Fc} \times 100 ,$$

where Fh is the upper frequency, Fl is the lower frequency and Fc is the centre frequency.

(e)Return loss

Return loss or reflection loss is the reflection of signal power from the insertion of a device in a transmission line or optical fiber. It is expressed as ratio in dB relative to the transmitted signal power. The return loss is given by:

$$RL(dB) = 10\ log\frac{Pr}{Pi},$$

where Pi is the power supplied by the source and Pr is the power reflected.

If Vi is the amplitude of the incident wave and Vr that of the reflected wave, then the return loss can be expressed in terms of the reflection coefficient Γ as:

$$Rl = -20log|\Gamma|,$$

and the reflection coefficient Γ can be expressed as:

$$\Gamma = \frac{\mathrm{Vr}}{\mathrm{Vi}}$$

For an antenna to radiate effectively, the return loss should be less than$-10\ dB$.

(f)VSWR

A standing wave in a transmission line is a wave in which the distribution of current, voltage or field strength is formed by the superimposition of two waves of same frequency propagating in opposite direction. Then the voltage along the line produces a series of nodes and antinodes at fixed positions.

If $V(z)$ represents the total voltage on the line then

$$V(z) = V^{+}e^{-j\beta z} + V^{-}e^{+j\beta z}$$

Then the Voltage Standing Wave Ratio (VSWR) can be defined as:

$$VSWR = \frac{Vmax}{Vmin} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

The value of VSWR should be between 1 and 2 for efficient performance of an antenna.

CHAPTER 3

Design of Microstrip patch antennas

3.1 Selection of patch parameters

In general, microstrip antennas are half wavelength structures and are operated at the fundamental resonant mode $TM01$ or $TM10$, with a resonant frequency given by:

$$f \cong \frac{C}{2L\sqrt{\epsilon r}}$$

where C is the speed of light, L is the patch length of the rectangular microstrip antenna, and εr is the relative permittivity of the grounded microwave substrate.

The radiating patch has a resonant length $L \propto \frac{1}{\sqrt{\epsilon r}}$, and the use of microstrip substrate with a large permittivity can result in a small physical antenna length at a fixed operating frequency.

With a size reduction at fixed operating frequency the impedance bandwidth of microstrip antenna is usually decreased. One can simply increase the substrate thickness to compensate for the decreased electrical thickness due to the lowered operating frequency. But as the height of the antenna increases losses due to surface wave effect and extraneous radiation result in poor performance characteristics.

Usually substrates with Ɛr $\leq$ 10 are preferred. With a substrate of low dielectric constant the fringing fields that account for radiation will be enhanced. But in order to obtain smaller patch size substrates with high εr are required. Thicker substrate besides being mechanically strong will increase the radiated power, reduce conductor loss and improve impedance bandwidth. But it increases the antenna weight, dielectric loss and surface wave loss.

3.2 Compact Broad band Design

One of the main disadvantages of microstrip antenna is its low bandwidth. In order to compensate for this various techniques has been studied. By the use of shorted patch with thicker air substrate can improve the bandwidth up to18%. Use of aperture coupled slots will help to get a bandwidth enhancement of up to 21%. Proximity coupling can also be used. Shorted patch with microstrip feed line can give better impedance matching and high bandwidth. By using two stack sorted patches one can obtain enhanced impedance bandwidth for a fixed antenna volume. But both the antennas should radiate almost equally and have a radiation quality factor as low as possible. Here by selecting the proper distance between the two offset shorting walls, one can achieve wide bandwidth. Microstrip antennas loaded with chip resistor and chip capacitor can also result in enhancement of bandwidth.

3.3 Compact dual frequency design

Microstrip antennas can be designed for dual band or triple band operation which finds great application in the field of satellite and mobile communication. Many promising designs of dual frequency operation with compact microstrip patch antennas have been reported. Either the two operating frequencies have the same polarization or orthogonal polarization planes.

Regular size microstrip antennas with a single feed and a single layer can give dual frequency operation by loading a pair of narrow slots close to the patch's radiating edges. Usually a pair of bent slots or step slots is embedded. By using notch square patches, dual frequency operation with orthogonal polarization planes can be achieved. Some novel dual frequency antennas can be obtained by using meandered rectangular patches. By incorporating a shorting pin in the center line of a rectangular microstrip patch and exciting the patch through a suitable feed position chosen from the center line, a good matching condition for the first two resonant frequencies of the microstrip antenna can be obtained, which makes possible the dual frequency operation using a single coaxial feed. Rectangular patches with cross slot of equal slot lines can also give good results. T-shaped slots, pair of bent slots can also be inserted for obtaining dual frequency operation.

3.4 Compact dual polarized design

The explosive growth in broadband wireless communication systems, with rapid advances in the variety and sophistication of the data intensive wireless servers being offered, has increased the demand to enhance the information accessibility and created a need for more bandwidth efficient communication techniques. It has been experimentally observed that by deploying dual polarized antennas the capacity of communication system can be increased. Circular polarized antennas can give better performance against reflection, absorption, penetration and bending effects as compared to linearly polarized antennas. Also the multipath fading effects due to the phase difference are less affected in circularly polarized antennas.

Dual polarization can be accomplished by exciting modes in two orthogonal directions, while size reduction can be achieved by means of slots from the surface of the patch. By using bent slots in parallel with patch's central line or the diagonal dual frequency operation can be achieved. By embedding pair of narrow slots of equal length in the ground plane is another method to achieve this.

Circular polarization can be achieved by using cross slots of unequal arm lengths and proper feeding of the patch. By introducing narrow slits in square patches compact circular polarized antennas can be obtained. Corner truncation of square patches with inserted slots can give good results with reduction in size. Also two orthogonal feeds with equal amplitude and phase quadrature can be excited to obtain circular polarization.

3.5 Design with enhanced gain

Most compact microstrip antenna designs show decreased gain owing to the small size. Gain enhancement is a major requirement for practical implementation of microstrip antennas. For implementation in practical applications the antenna gain should be at least 6 dB at the operating frequency.

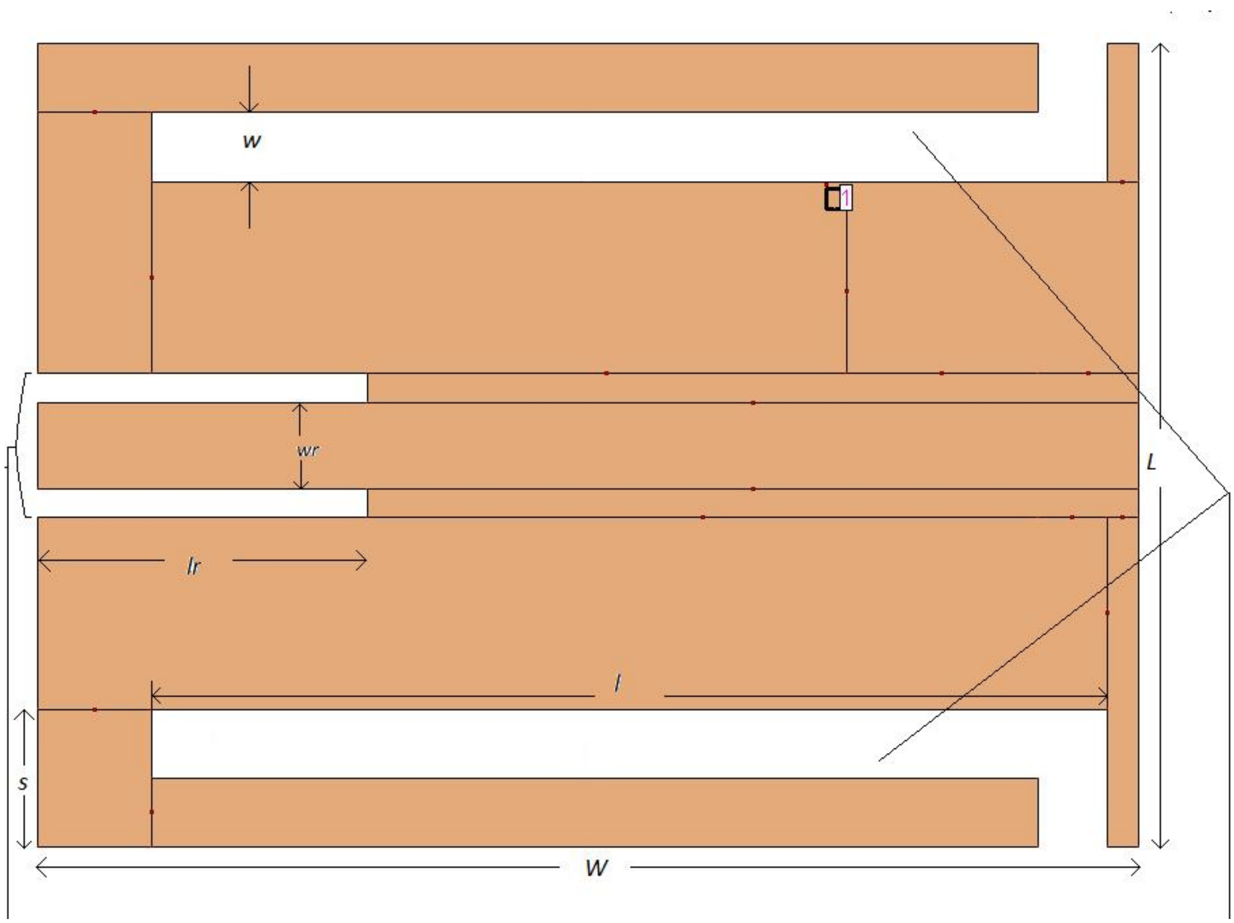
The simplest way to enhance the gain is to use high permittivity substrate like ceramic superstrate of very high dielectric constant. Such substrates can be loaded on to antennas with low gain in order to obtain satisfactory results. By integrating amplifier circuitry with a dc bias feedback resistor on to passive microstrip antenna can improve the gain.

CHAPTER 4

Design and analysis of dual band and dual polarized Microstrip patch antenna

4.1 Design of Dual – Frequency Rectangular Microstrip Antenna with a pair of spur lines and integrated reactive loading

Dual – frequency microstrip antenna can be designed by inserting a pair of embedded spur lines and integrated reactive loading [5]. Both the operating frequencies will have same polarization planes. The embedded spur lines are at patch's non – radiating edges, and integrated reactive loading is obtained by an inset microstrip – line section and inserted at one of the patches radiating edges.



Reactive loading Embedded spur lines

Figure 4.1 Basic dual frequency patch

4.1.1 Basic Geometry

The basic geometry of the patch is given in figure 4.1.

The length L and width W of the patch are given by:

$L = 38mm$, $W = 27.5mm$

The substrate chosen has a dielectric constant ϵr given by:

$\epsilon r = 4.4$, with a loss tangent $tan\delta = 0.025$

The height h of the substrate is chose to be

$h = 1.6mm.$

The embedded spur lines ate formed by inserting two slits of equal geometry on either side of the patch's non – radiating edges.

The length l and width w of the spur lines are given by:

$l = 33mm$, and $w = 2.4, mm.$

The distance of the spur line from the edge of the patch is given by:

$s = 4mm.$

The inset microstrip – line section forms the integrated reactive loading. The dimension of this inset 50Ω microstrip – line section to improve good impedance matching are fixed at $lr = 0.3L$ and $wr = 3mm.$

So the values chosen for the length lr and width wr of the inset microstrip – line section are given by:

$lr = 11.4mm$, and $wr = 3mm.$

The width of each microstrip – line section is chosen to be$1mm$.

Coaxial feeding is done diagonally at the point marked as (1). Coaxial feeding is done at the point $P(x, y)$ given by:

$\mathrm{P(x, y)} = (8.6,8.6)$.

4.1.2 Modes of operation

In this design a new resonant mode with its resonant frequency lower than that of the $TM10$ mode can be excited. This new resonant mode is denoted the $TM\beta0$ mode $(0 < \beta < 1)$; it has the same polarization plane as the $TM10$ mode. The resonant frequency of the $TM\beta0$ mode is found to be strongly dependent on the spur-line length. On the other hand, since the embedded spur lines are oriented mainly parallel to the patch edges, a very small effect on the performance of the $TM10$ mode is expected; that is, the resonant frequency $f10$ will be very slightly affected by the spur-line perturbation. The different effects of the embedded spur lines on the $TM\beta0$ and $TM10$ modes make the frequency ratio of the two operating frequencies tunable and result in an even lower frequency ratio than that obtained for usual patches as given by [5].

4.1.3 Simulation Results

The microstrip patch antenna was designed using IE3D simulator. The performance of the antenna has been studied by comparing the Return loss, VSWR, Z parameter, Gain, azimutal and elevation patterns.

4.1.3.1 Return Loss

The simulation results for the return loss for the frequency range from 7 to 10 GHz are shown in the figure 4.2.

In figure 4.2(a) the effect of variation of spur-length is shown. In figure 4.2(b) the effect of variation of distance of the spur-line from the edge of the patch is shown.

In figure 4.2(a) the effect of variation of spur-line width is shown.

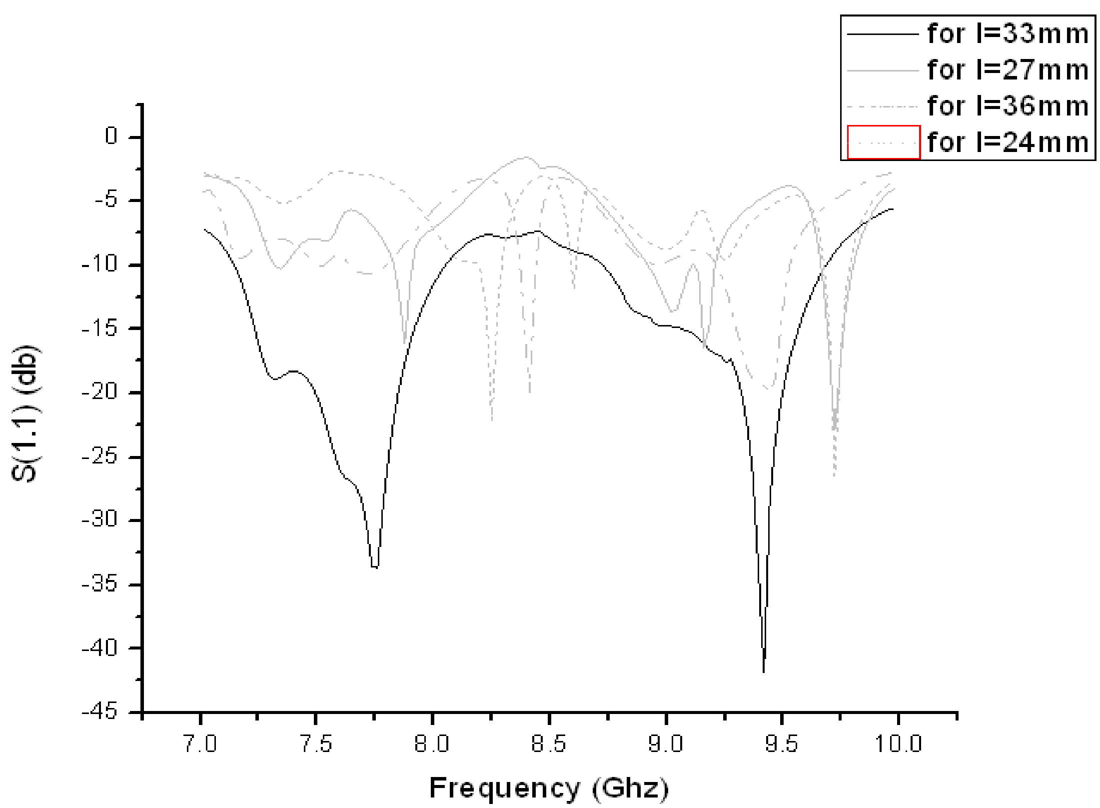


Figure 4.2(a) Effect of changing the spur length l on the Return Loss

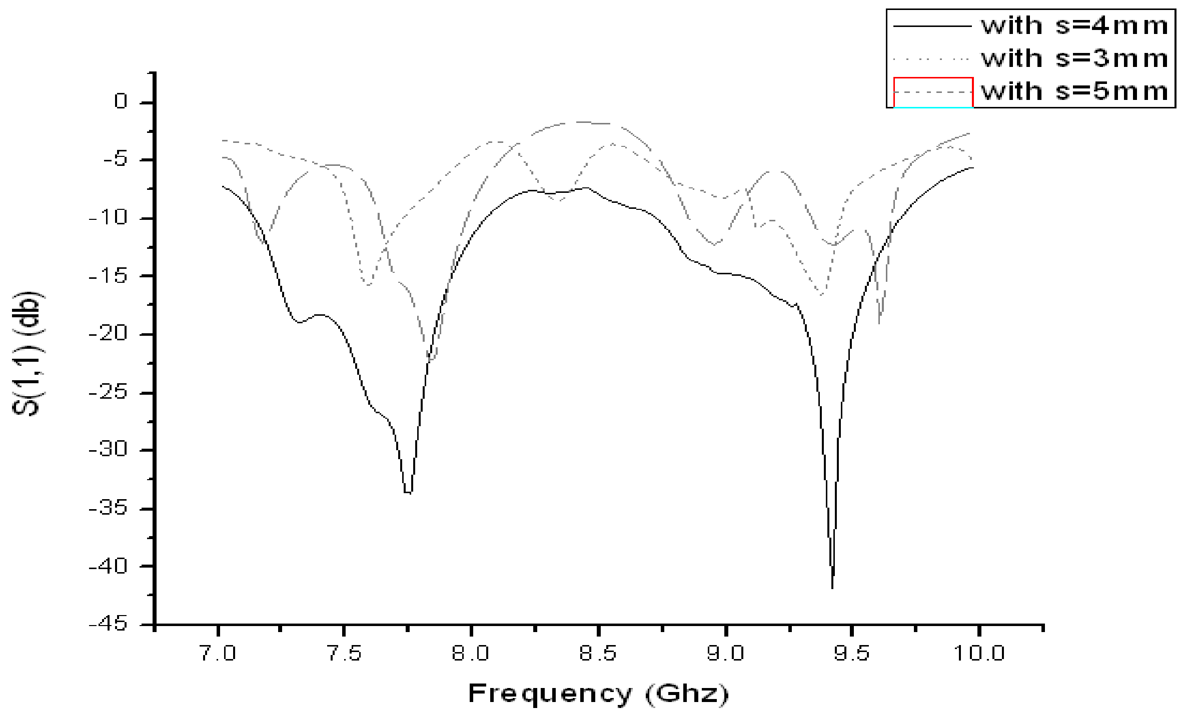


Figure 4.2(b) Effect of changing the distance of spur line from the patch edge on the Return Loss

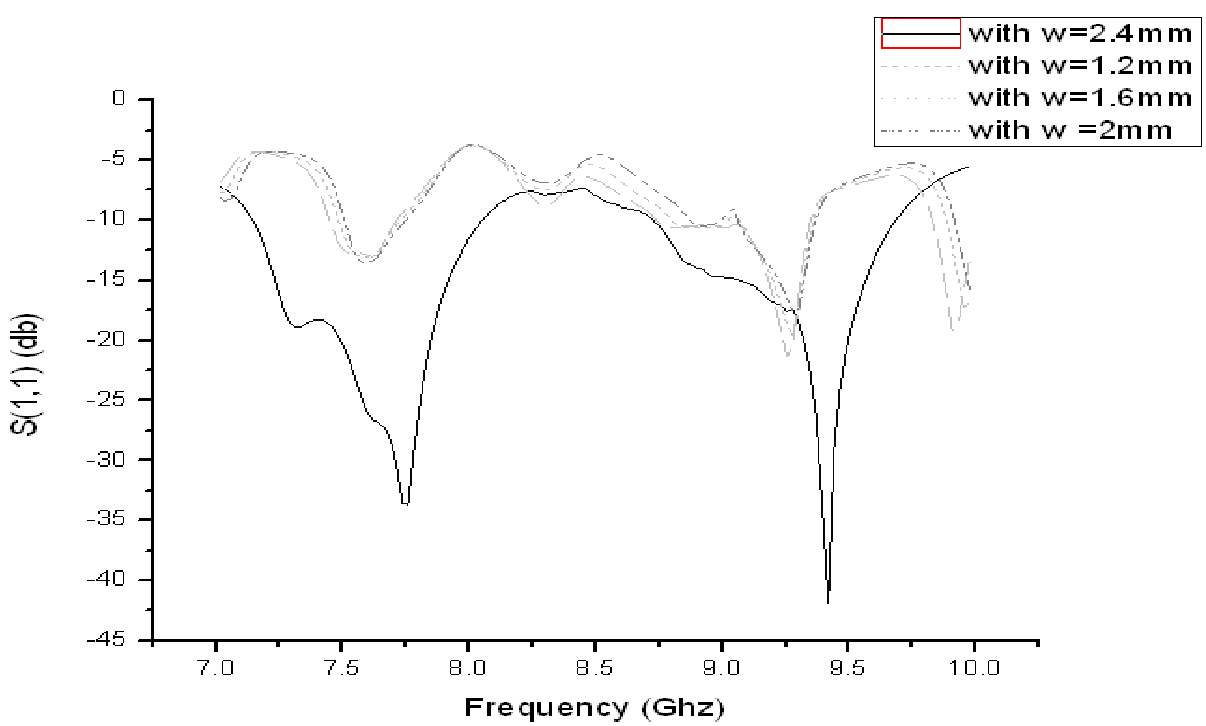


Figure 4.2(c) Effect of changing the spur width w on the Return Loss

From the s parameter display the two operating frequencies can be centered at $fc1 = 7.62GHz$, with $S(1,1) = -34.01dB$ and $fc2 = 9.37GHz$, with $S(1,1) = -45.84dB$.

The bandwidth can be calculated by taking 10dB as the reference line.

For the first frequency band centered at fc1

$fl1 = 7.15GHz$ and $fh1 = 8.04GHz$.

So the bandwidth $BW1 = \frac{8.04-7.15}{7.62} \times 100 = 11.68\%$.

For the second frequency band centered at fc2

$fl2 = 8.74GHz$ and $fh2 = 9.67GHz$.

So the bandwidth $BW2 = \frac{9.67-8.74}{9.37} \times 100 = 9.93\%$.

4.1.3.2 VSWR

The simulation results for VSWR for the frequency range from 7 to 10 GHz is shown in the figure 4.3.

In figure 4.3(a) the effect of variation of spur-length is shown. In figure 4.3(b) the effect of variation of distance of the spur-line from the edge of the patch is shown.

In figure 4.3(a) the effect of variation of spur-line width is shown.

The value of VSWR can be seen to be within 1 to 2 in the operating range.

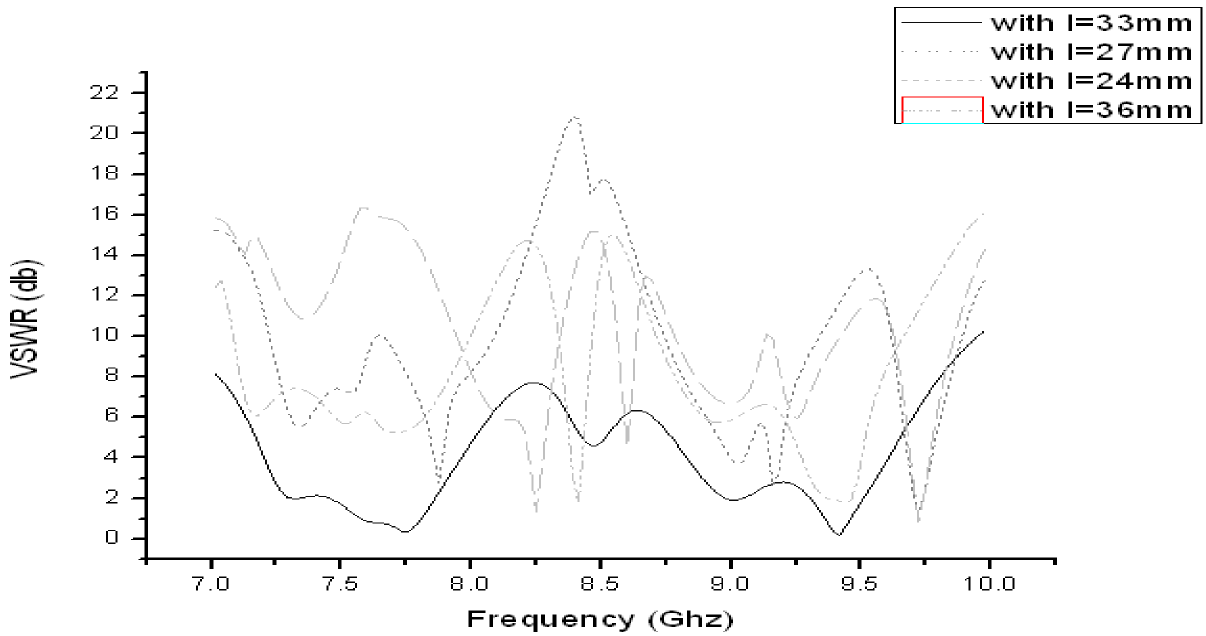


Figure 4.3(a) Effect of changing the spur length l on the VSWR

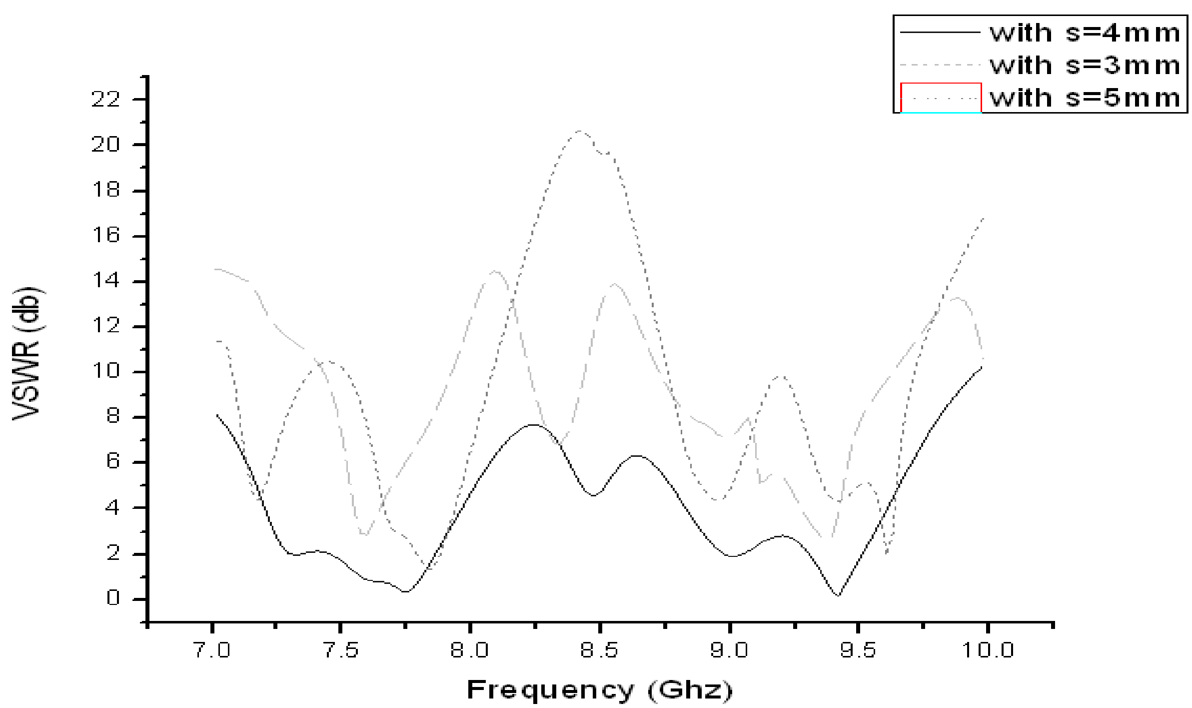


Figure 4.3(b) Effect of changing the distance of spur line from the patch edge on the VSWR

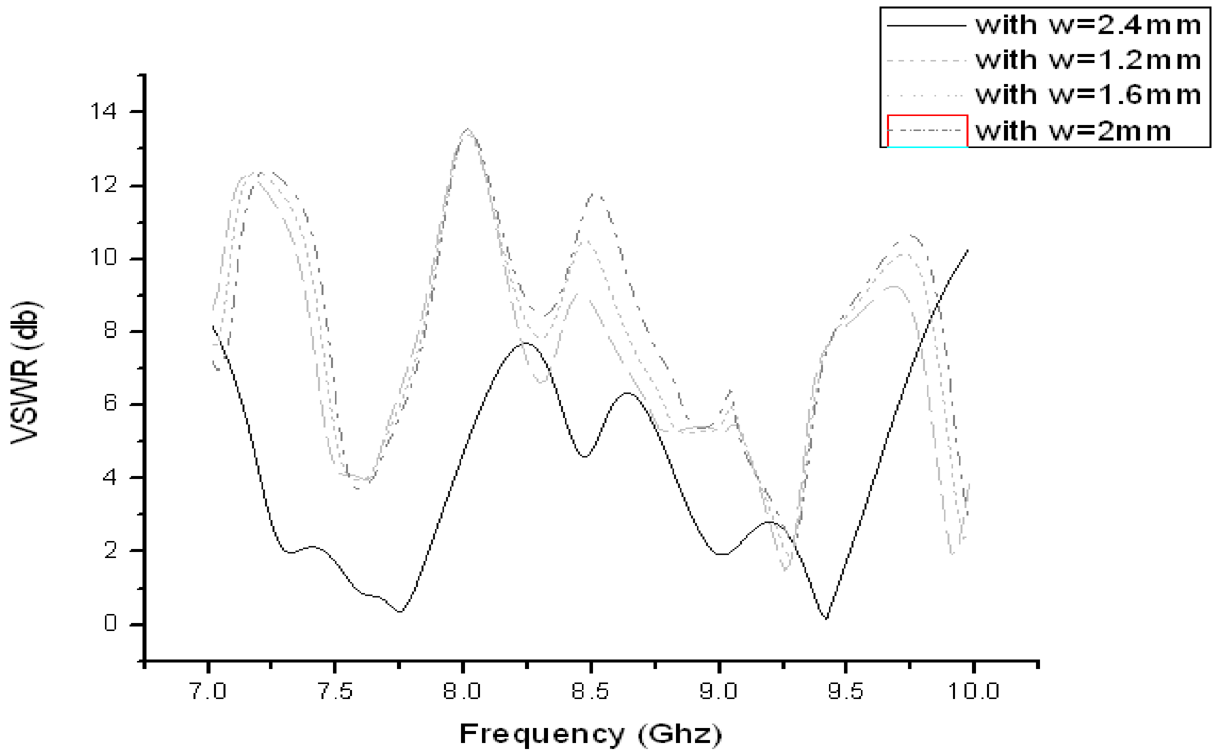


Figure 4.3(c) Effect of changing the spur width w on the VSWR

4.1.3.3 Z Parameter

The simulation results for Z Parameter for the frequency range from 7 to 10 GHz is shown in the figure 4.3.

In figure 4.4(a) the effect of variation of spur-length is shown. In figure 4.4(b) the effect of variation of distance of the spur-line from the edge of the patch is shown.

In figure 4.4(a) the effect of variation of spur-line width is shown.

The value of Z parameter can be seen to be around 50Ω in the operating range.

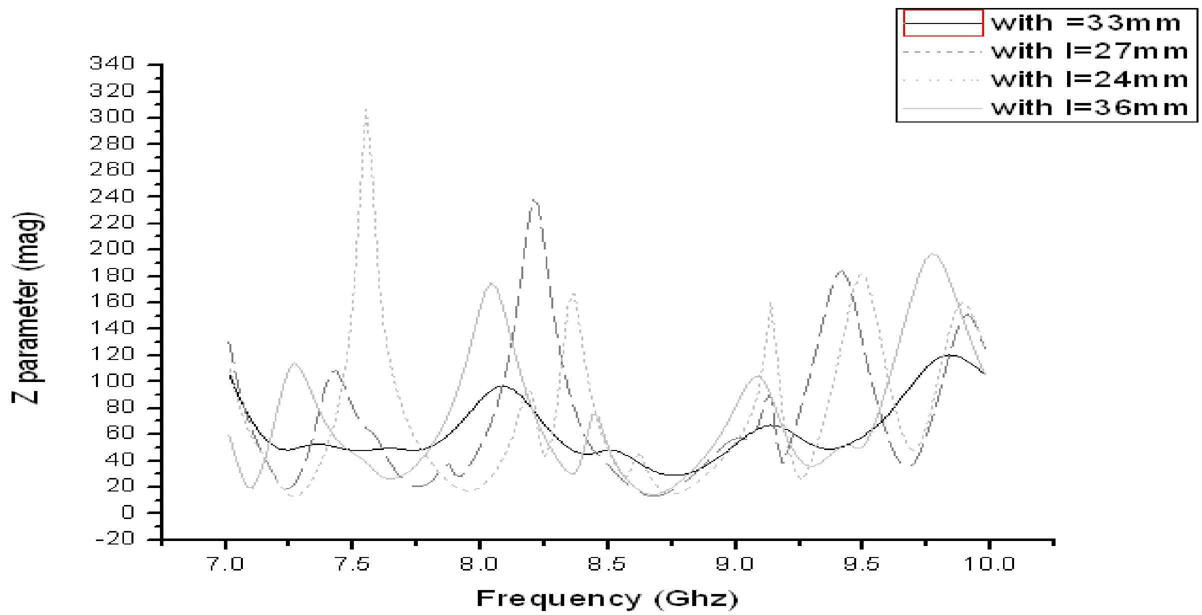


Figure 4.4(a) Effect of changing the spur length l on the z parameter

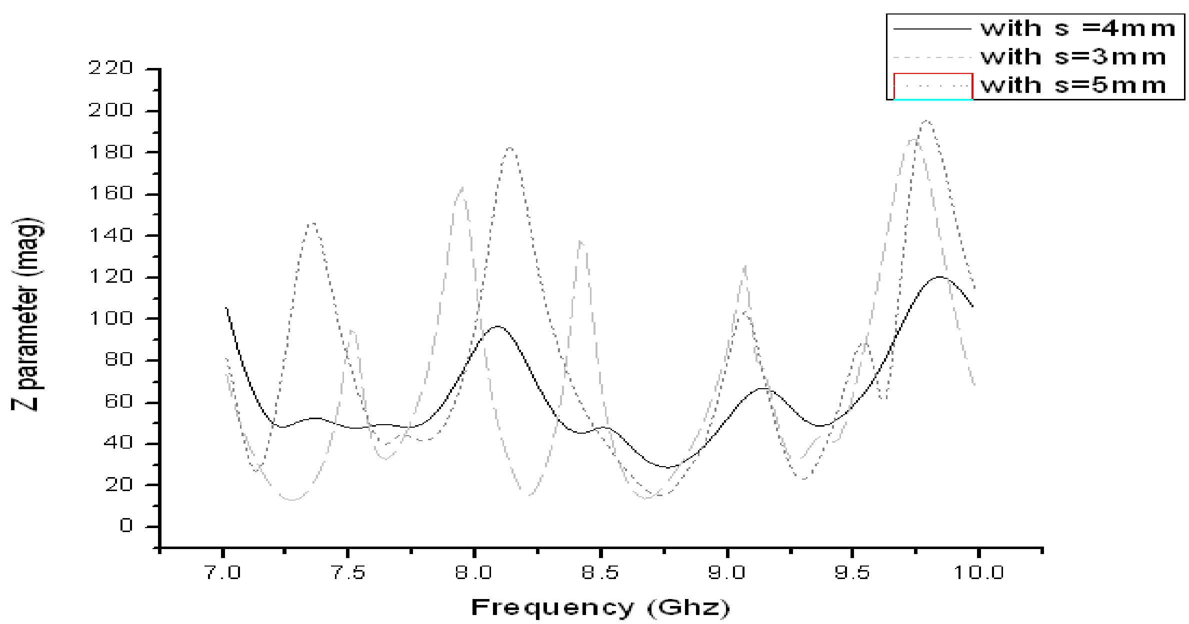


Figure 4.4(b) Effect of changing the distance of spur line from the patch edge on the Z Parameter

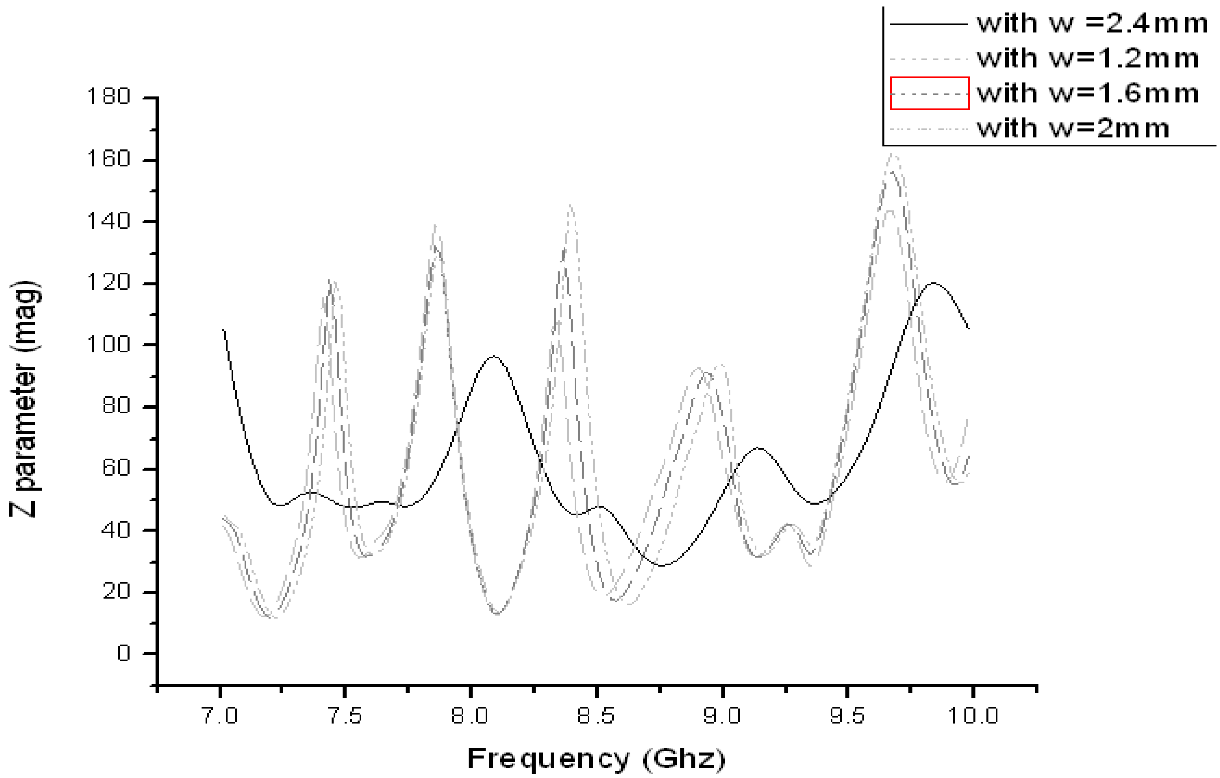


Figure 4.4(c) Effect of changing the spur width *w* on the z parameter

4.2 Design of Dual Band Dual polarized Microstrip Patch Antenna with a pair of spur lines, integrated reactive loading and a cross slot

By incorporating cross slots of unequal lengths in a microstrip patch antenna and probe feeding at 45° to the two arms of the cross slot, circular polarization can be obtained. Here the splitting of the TM_{10} mode into two near-degenerate orthogonal resonant modes occurs. By further selecting the proper slot length and feeding the patch at a suitable position, the two near-degenerate orthogonal resonant modes can have equal amplitudes and a 90◦ phase difference, and CP operation can thus be obtained [6].

In order to obtain dual polarization cross slot of unequal length has been introduced to the basic patch so as to facilitate linear and circular polarization.

4.2.1 Modified patch with a cross slot at the center

The basic patch is shown in figure 4.5.

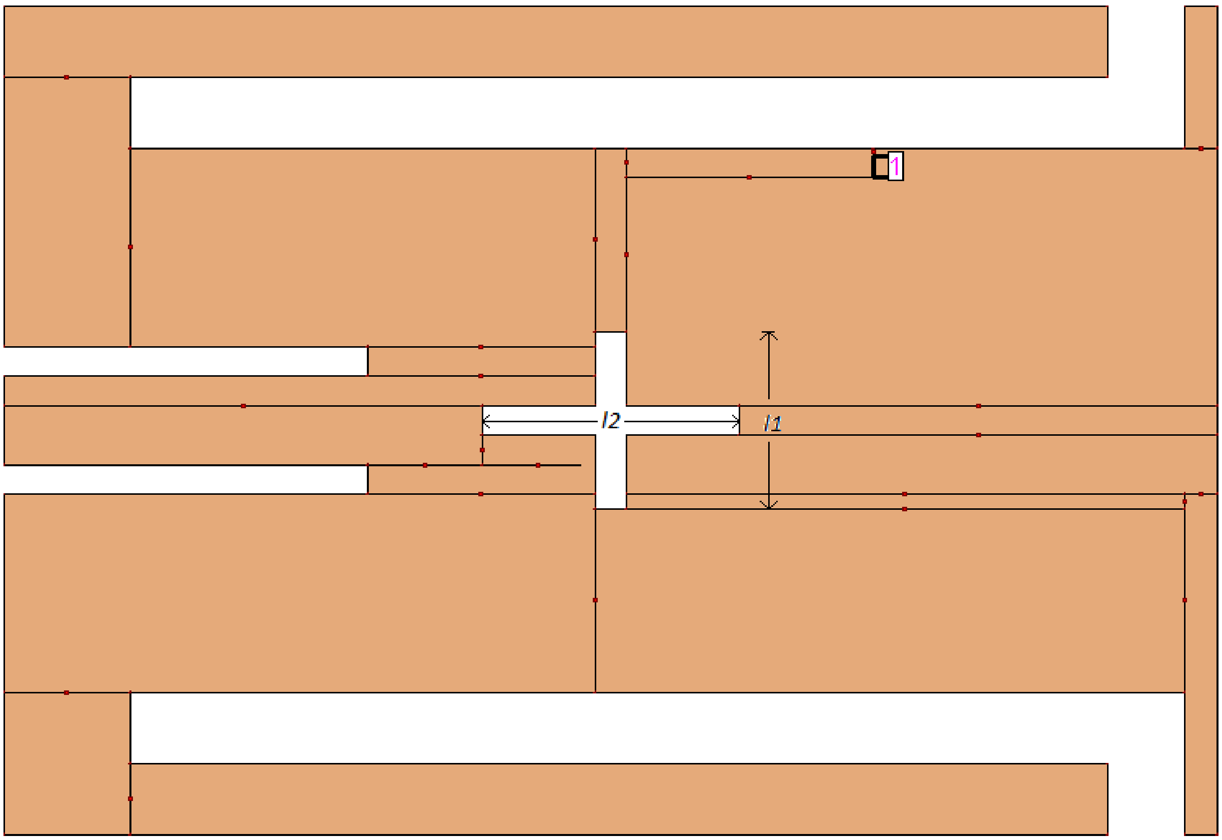


Figure 4.5 Modified patch for dual band and dual polarization.

The length of the cross slots along the vertical direction $l1$ and that along the horizontal direction $l2$ are selected to be

$l1 = 6mm$ and $l2 = 8mm$.

4.2.2 Simulation Results

All the parameters for the modified patch is discussed here.

4.2.2.1 Return Loss

The simulation results for return loss for the frequency range from 7 to 10 GHz are shown in the figure 4.6.

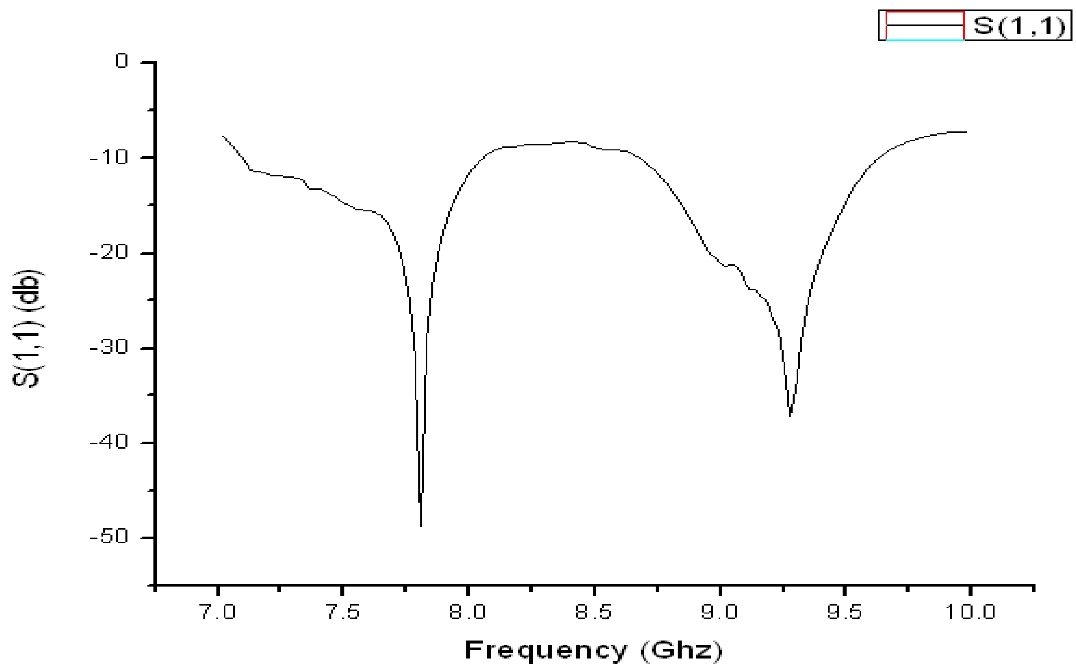


Figure 4.6 S parameter v/s Frequency plot

From the s parameter display the two operating frequencies can be centered at

$fc1 = 7.81GHz$, with $S(1,1) = -48.71dB$ and $fc2 = 9.28GHzw$, with $S(1,1) = -37.23dB$.

The bandwidth can be calculated as discussed above.

4.2.2.2 VSWR

The simulation results for VSWR for the frequency range from 7 to 10 GHz are shown in the figure 4.7.

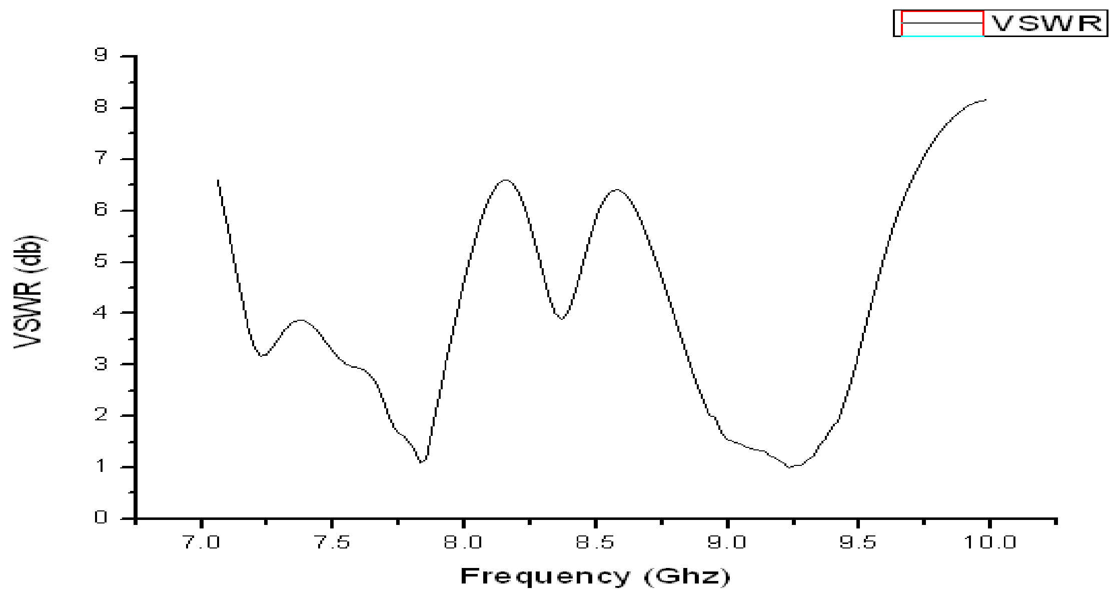


Figure 4.7 VSWR v/s Frequency plot

4.2.2.3 Z Parameter

The simulation results for z parameter for the frequency range from 7 to 10 GHz are shown in the figure 4.8.

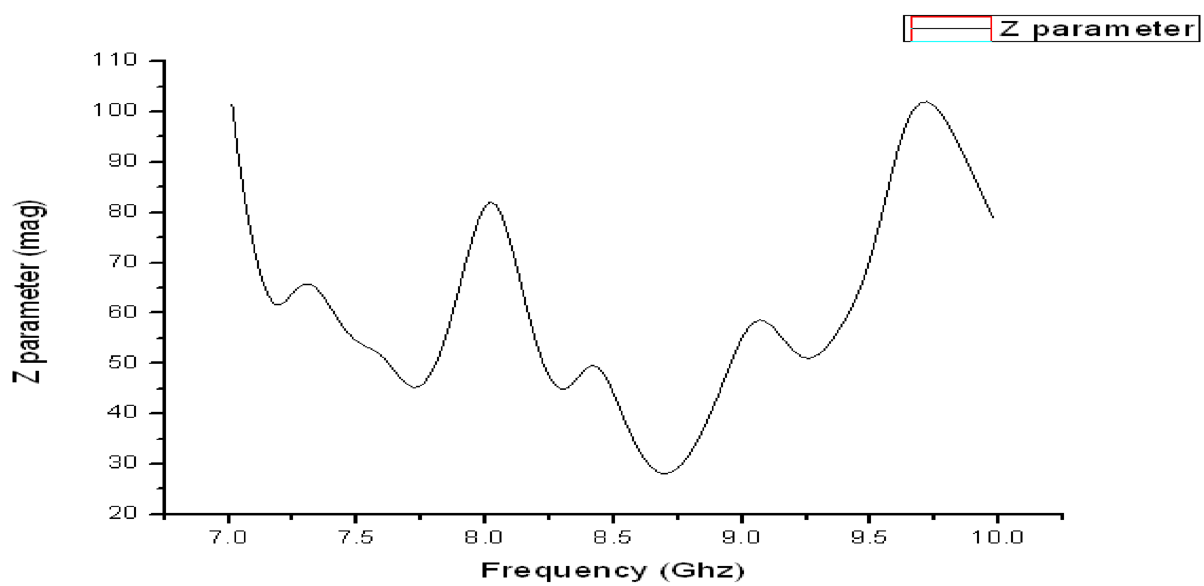


Figure 4.8 Z parameter plot for input impedance (Zc)

4.2.2.4 Axial Ratio

The axial ratio gives the ratio of electric field along the x and y directions. In order to obtain circular polarization the axial ratio should be 1.

The simulation result for axial ratio is shown in figure 4.9.

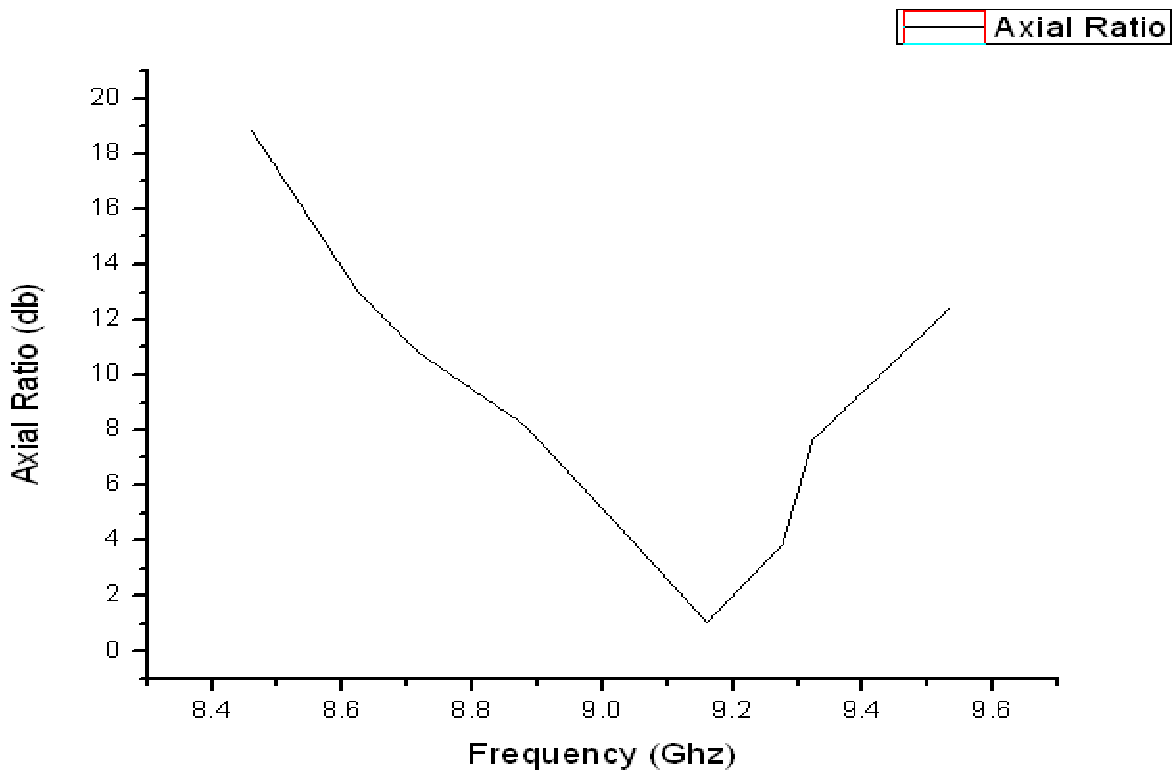


Figure 4.9 Axial ratio v/s Frequency plot

From the figure the axial ratio is obtained to be 1.036 at a frequency 9.16GHz.

4.2.2.5 Gain

Microstrip antennas have very poor gain. But in order to be used in real life applications the gain should be more than 6dBi.

The simulation results for the antenna gain in dB is shown in figure 4.10

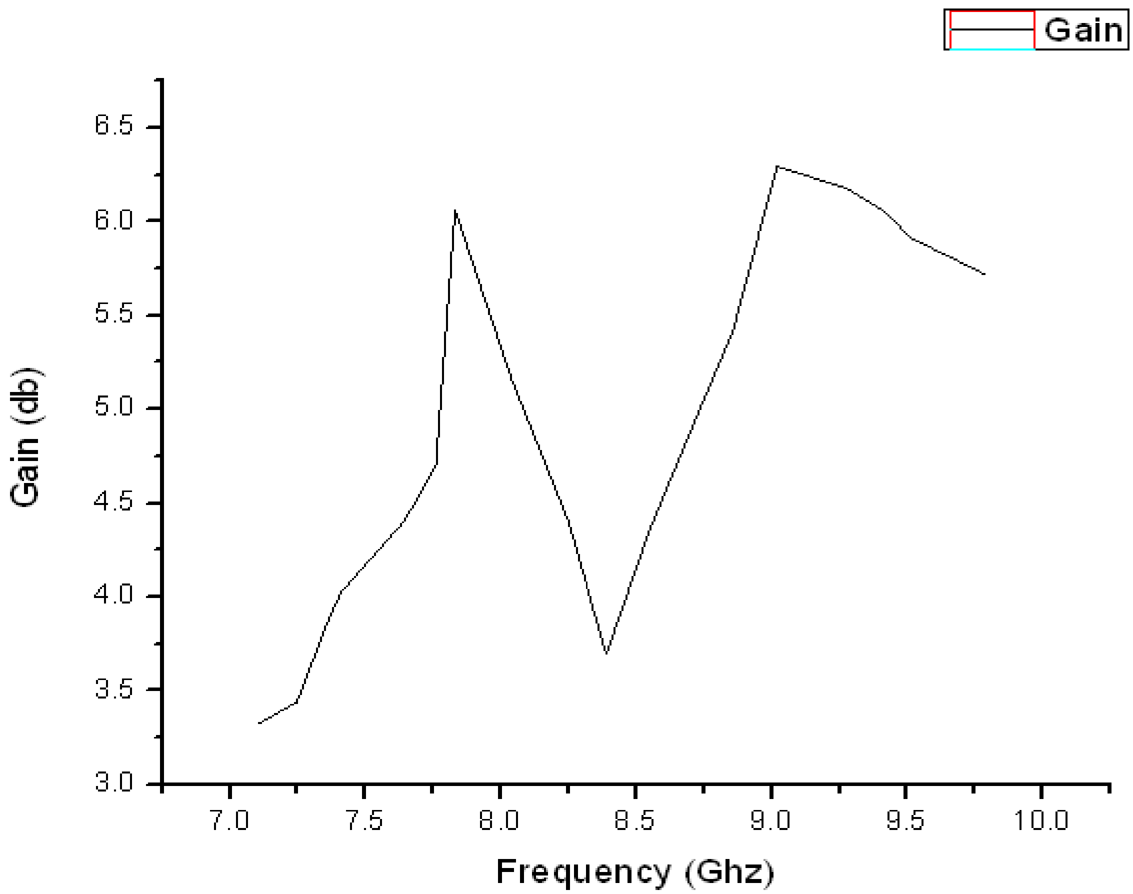


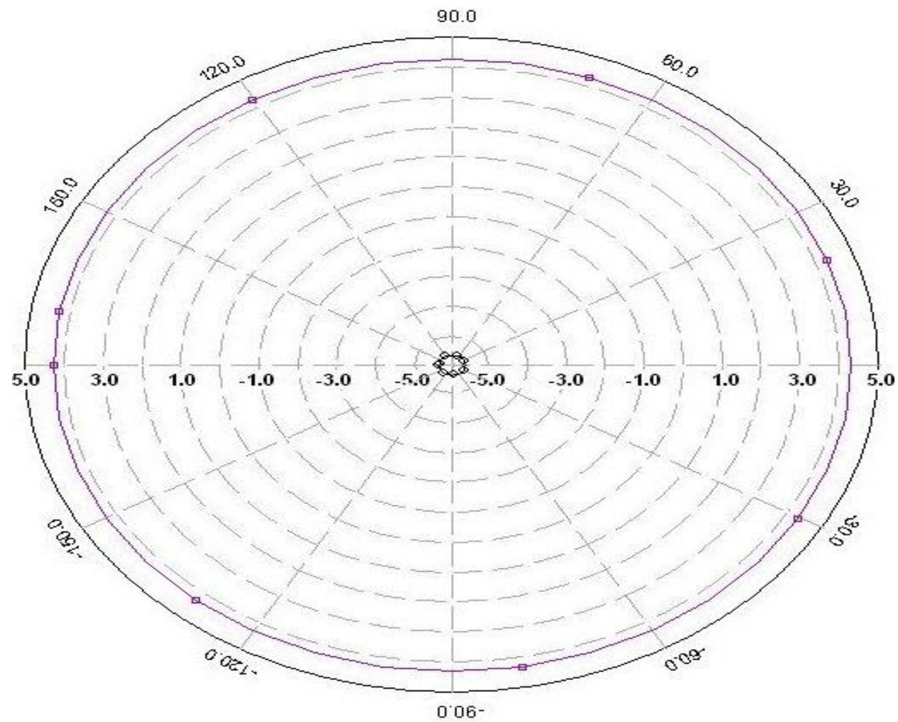
Figure 4.10 Gain v/s Frequency plot

The value of gain in dB at the two central frequencies is obtained to be 6.06dBi at 7.83GHz and 6.05dBi at 9.42GHz.

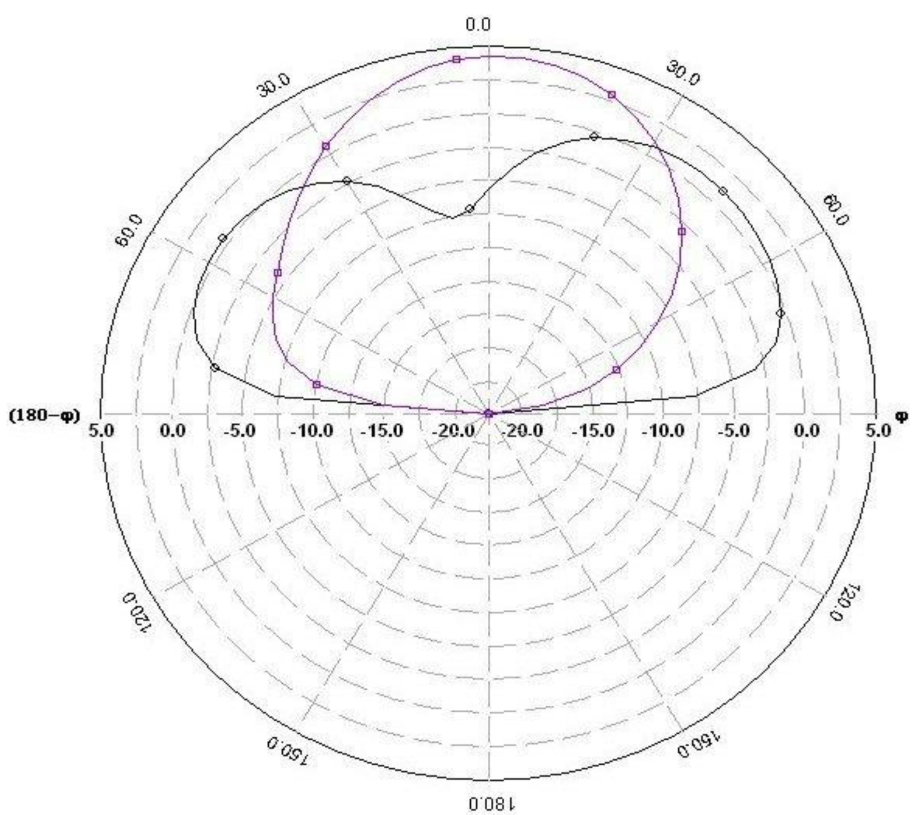
4.2.2.6 Radiation Patterns

The radiation pattern can be obtained from the Azimutal and Elevation pattern gain displays in dB.

The Azimutal pattern gain display is shown in figure 4.11(a) and the Elevation pattern gain display is shown in figure 4.11(b).



4.11(a) Azimutal pattern (H-Plane) gain display



4.11(b) Elevation pattern (E-Plane) gain display

Chapter 5

Conclusions

The work in this thesis primarily focuses on the design of dual band and dual polarized microstrip antennas. The work reported in this thesis is summarized in this chapter. Section5.1 lists the achievements of the work. 5.2 lists the limitations and 5.3 provide some scope for further development.

5.1 Achievements

Dual band and dual polarization operation were successfully incorporated into a single patch. The effect of varying the slit length, slit width and slot length were studied under great details with the help of experimental results. The proposed patch yield desirable results throughout the operating frequency range. Above all, the antenna was found to produce a gain of around 6 dBi and bandwidth of around 10% at the operating frequency ranges.

5.2 Limitations

The following limitations when encountered during the course of this project.

The substrate thickness has to be increased in order to obtain high gain and improved bandwidth. So microstrip patch antennas usually suffer from very low gain and bandwidth. But increasing the substrate thickness produces surface wave loss and extraneous radiations.

The operating frequencies of the designed patch were obtained at 7.81 and 9.28 GHz. In order to find application in the field of mobile communication the frequency range has to be within 1 to 3 GHz. So the length and the breadth of the patch can be further adjusted to reduce the resonant frequency of operation to this range. Also the use of microwave substrate with large permittivity can result in small physical antenna size at a fixed operating frequency. But while increasing the permittivity one has to be careful about the losses due to surface wave effects.

5.3 Suggestions for Future Work

A method for reducing the operating frequency range can be combined with the proposed patch for application in the field of mobile communication. The optimization of the patch can be done using PSO coding. This will help to improve the radiation efficiency and gain of the antenna. At present facility for fabrication of the patch is not available in our institute. The same work will be performed later. Also the gain and bandwidth can be improved by implementing suitable methods for the same.

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