"A Patch Antenna Loaded with Varactor For Multiband Operation using Fractals In Reconfigurable Antenna"

DISSERTATION-II

Submitted in partial fulfillment of the

Requirement for the award of the

Degree of

MASTER OF TECHNOLOGY
IN
(Electronic and Communication Engineering)

By
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Under the Guidance of
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MAY 2017

CERTIFICATE

This is to certify that ‘Jyotika Sawhney’ bearing Registration no. 11203083 has completed objective formulation of thesis titled, **“A Patch Antenna loaded with Varactor for Multiband Operation using Fractals in Reconfigurable Antenna.”** under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of the master’s degree

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Also my special thanks to all class fellows and seniors, who helped me in clarification of any issue as well as implementation and documentation**.**

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I Jyotika Sawhney, student of B.Tech-M.Tech (Dual Degree) under Department of Electronics and Communication Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

With the headway in the rise of the wireless communication over the last years, there lies the need of miniaturization in antenna's size, multiband and low cost. So as to meet all these requirements, Fractal antenna design is preferred. Along with these advantages, realization of the fractal antenna can be enhanced with the concept of reconfiguration. In this paper the Reconfigurability is being achieved with the help of varactor diodes (SMV 1430) that is being placed in the patch with the electronic dc biasing equipped at the right side of the patch and the left side of the patch is being loaded with the fractals so as to obtain the multiband application and miniaturization in size of the antenna. The Proposed antenna is being designed and simulated using Ansoft-High Frequency Structure Simulator (HFSS). The proposed antenna is being operated at 2.45GHz yielding after simulation four resonant frequency that are nearly constant covering band of 2.26-2.31GHz,5.0251GHz,7.06-7.15GHz,9.54-9.59GHz.The Gain obtained is 7.63dB.The Proposed antenna can be used in applications such as WiMAX, WLAN, Satellite, LTE etc.

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List of Abbreviations

PCB	Printed Circuit Board
MMIC	Monolithic Microwave Integrated Circuit
TEM	Transverse Electro Magnetic
LTE	Long Term Evolution
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WWAN	Wireless Wide Area Network
RHCP	Right Hand Circularly Polarized
LHCP	Left Hand Circularly Polarized
PIN	p-type, intrinsic region, and n-type
SPIN	Surface PIN
MEMS	Micro-Electro-Mechanical-System
DC	Direct Current
UWB	Ultra Wide Band
WCDMA	Wireless Code Division Multiple Access
RF	Radio Frequency
LTSA	Linearly Tapered Slot Antenna
GSM	Global System for Mobile

Chapter 1
INTRODUCTION

1.1Antenna

Antenna is used as a source for 'transmission and reception of the radio waves'. Also it is the transitional configuration linking the guiding device with the free-space. The transmission line can be coaxial or hollow pipe, i.e. basically used to transfer the electromagnetic energy from the transmitter to receiver or receiver to transmitter.

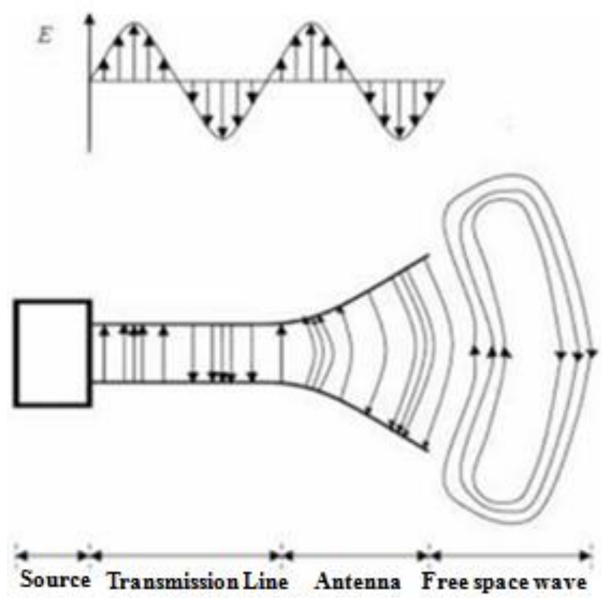


Fig.1 Antenna as a transitional device [1]

Antenna's system thevenin equivalent is given in Fig.2 in where source is indicated by the ideal generator and the transmission line is indicated by the line that has characteristic impedance as Z_C and also the antenna is indicated by the use of load that has characteristic impedance as Z_A, i.e.Z_A= $[(R_L+R_r) + jX_A]$ that is associated with the line of transmission. The resistance that is indicated by R_L helps to depict the losses i.e. dielectric losses and the conduction losses that are being related with the structure of Antenna [1]. The radiation resistance indicated by R_r that helps to describe the antenna radiation. The Reactance that is being indicated by X_A is useful so as to depict the impedance imaginary part that is being linked with the antenna's radiation. It is stated in the initial setting that the energy being created by the source should be fully transported to R_r. But practically many losses i.e. conduction and dielectric losses are present due to the lossy nature of transmission line as well as antenna. When considering only internal impedance and neglecting the losses then the amount of power delivered to the antenna is maximum under conjugate matching.

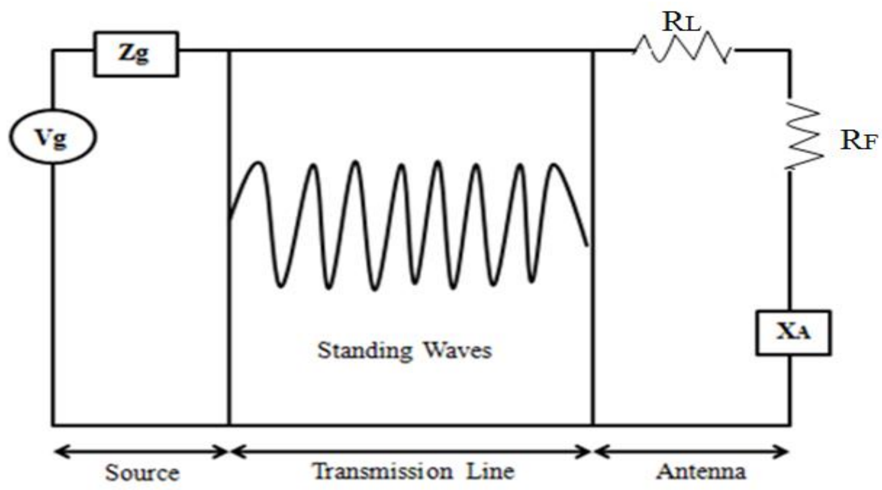


Fig.2 Thevenin Equivalent Model in transmitting mode.

The waves reflected from the surface plus the travelling waves from the starting point to end point create the interference i.e. constructive and destructive interference pattern which is called as the standing waves.

Besides transmitting and receiving energy, an antenna is also used to gain the energy radiated in several directions and restrain it into other direction. Therefore, antenna ought to serve the same as directional device accompanying with the probing device. It should acquire the diverse forms to fulfill the demand as a wire that conducts, reflector, a patch, antenna array and a lens etc.

An antenna is the individual most essential element in the wireless communication system. By designing good transmitter and receiver i.e. antenna it can improve the overall performance of the antenna. Example for this is television in which the overall broadcast reception can be improved with the help of high-performance antenna [1]. The antenna is same for the communication system as eyes and eyeglasses for human being.

1.2Types of Antenna:

1.2.1 Wire Antennas:

This antenna is very well known by the layman as it can be seen everywhere like automobiles, ships, aircraft, spacecraft, buildings, etc. There are many shapes of wire antenna available like straight wire (dipole), loop, and helix. Various configurations of wire antenna is shown in Fig.3

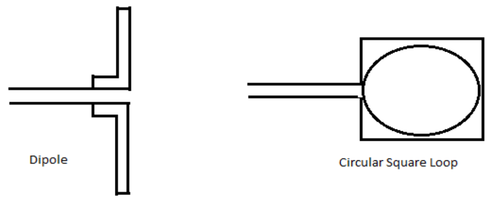


Fig. 3 Configuration of wire antenna

1.2.2Aperture Antenna:

This particular type of antenna is used in space craft as well as aircraft because it can be readily flush-mounted over the skin of the spacecraft or aircraft. Additionally it is covered with dielectric material to keep safe them from haphazard conditions of atmosphere

1.2.3Microstrip Antennas:

It gained importance during 1970's basically for applications used in space. Nowadays they are very much helpful in commercial as well as government applications. Microstrip antennas comprise of metallic patch mounted over a ground substrate. Patch has many configurations. These types of antenna are basically of low profile, applicable to non-planar as well as planar surfaces. Microstrip antennas are not that complex as compared to others. They are easy to implement and very cost effective to formulate using technology of PCB also involuntarily vigorous whenever placed on the surfaces that are rigid, chiefly resourceful in respect of frequency, impedance, polarization and pattern, very much suited with MMIC designs.

These types of antennas can be placed over the roof of the spacecraft, cars, aircraft, missiles, satellites, and mobile, telephones. Various configurations of Microstrip antennas is being shown in Fig.4 [1]

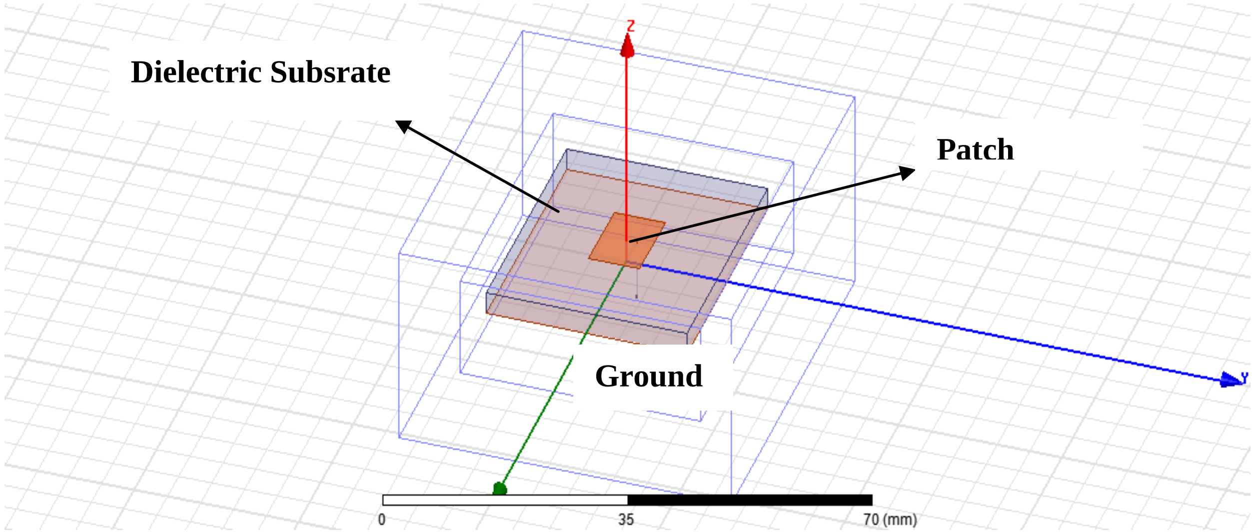
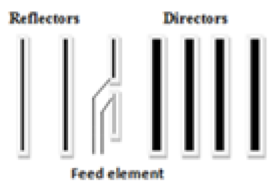


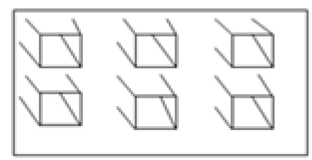
Fig.4 Configurations of Microstrip Patch Antenna

1.2.4Array Antennas:

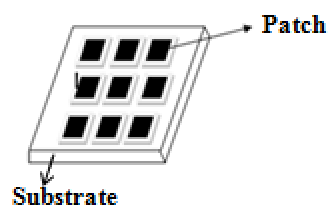
There are numerous applications available that necessitate radiation characteristic which is sometimes not possible by the only element. Then it might be likely to take average of different r elements radiating in different arrangement such as geometrical as well as electrical arrangement i.e. array that provides outcome as required radiation characteristic.These arrays must be arranged in such a way that different a radiation from all the elements sums up so as to give rise to maximum radiation in the desired direction. Various configurations of Array antenna is shown in Fig.5 [1]



a. Yagi Uda Array



b. Aperture Array



c. Microstrip Patch Array

Fig. 5 Configurations of the Array antenna

1.2.4 Reflector Antennas:

These types of antenna are manufactured with the range having diameter equal to 305 m. With this large dimension it is possible to achieve the high gain that is suitable to transmit and receive the signals after travelling so much distance.

1.2.5 Lens Antennas:

The main use of lens is to gather the incident energy to prevent it from spreading in various different directions that are not desired. If geometrical configurations are properly shaped as well as selected the best suited material for the lenses, they can be transforming the divergent energy into plane waves. They are used for many applications such as parabolic reflectors, usually on the surpassing frequencies. Their size can be made large at lower values of frequencies. Classifications of these antennas are based on the type of material they are prepared of. Various configurations of lens antennas are shown in Fig.6 [1]

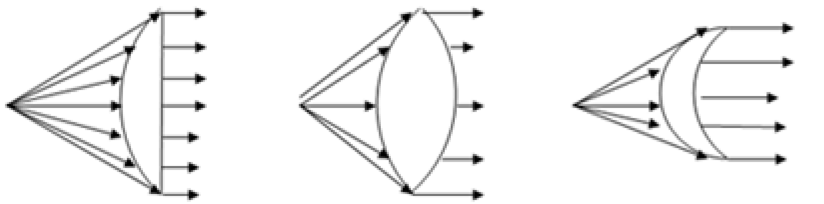


Fig.6 Configurations of Lens Antenna

1.3 Parameters of Antenna

1.3.1Radiation Pattern: It is the demonstration of the radiation properties of antenna graphically that is the role of co-ordinates in space. The power pattern of antenna is frequently plotted in dB (decibels) or sometimes in logarithmic scale.

1.3.2Radiation Intensity: It is "the power radiated from the antenna per unit solid angle." Basically it is a far-field pattern which has been obtained by simply multiplying the distance square with the radiation density. Mathematically it can be expressed as:

$$U = r^2 Wrad \qquad (1)$$

1.3.3Beamwidth: It is described as the separation (angular) among two same points lying on the contrary side of pattern maximum. There are number of beamwidths. The Half-Power Beamwidth (HPBW) is used generally that is described as 'The angle between the two particular directions where the intensity of radiation is equal to 1/2 of the beam.' First-Null Beamwidth (FNBW) is the second beamwidth and is described by the separation but angular separation within the first nulls of the pattern. Formulae for vertical beamwidth and horizontal beamwidth is given in Eq.2 and Eq.3 [1]

$$\text{Horizontal Beamwidth} = 115\frac{\lambda}{L} \qquad (2)$$

$$\text{Vertical Beamwidth} = 50\frac{\lambda}{L} \qquad (3)$$

1.3.4 Directivity: It is the portion of the radiation intensity in a desired direction from the antenna and the radiation intensity that is summed from all the directions where radiation intensity is the radiated power by the antenna divided by 4π. Formula is given by [1]:

$$D = \frac{U}{Uo} = \frac{4\pi U}{Prad} \qquad (4)$$

Whenever direction is not provided, maximum directivity then expressed by the Eq.5

$$Dmax = Do = \frac{Umax}{Uo} = \frac{4\pi Umax}{Prad} \qquad (5)$$

1.3.5Gain: It is the fraction of intensity in a desired route and radiation intensity which can be occupy if the power received by the surface of the antenna is radiated in every possible direction i.e. isotropically. Gain is given by [1]:

$$Gain = 4\pi \frac{\text{radiation intensity}}{\text{total input(accepted)power}} = 4\pi \frac{U(\theta,\varphi)}{Pin} \qquad (6)$$

1.3.6 Polarization: Antenna purpose is to convert current to that waves that are electromagnetic in nature that is then being emanate into space. The electric field plane that is sometimes described by 'E' plane identifies the polarization or the orientation of radio wave. Mostly antennas radiate in either linear or circular polarization.

1.4 Microstrip Patch Antenna

Usually in aircraft, space-craft, satellites, missiles applications where there are constraints such as cost, weight, and size, performance and mechanism, then the need of low profile antennas arises. Also there are alike many application in the government and commercial industry with the same specification. To accomplish these specifications or requirements, Microstrip antennas are used. These types of antennas are usually called as low profile antennas and are applicable to both non-planar and planar surfaces. Microstrip antennas are not that complex as compared to others. They are easy to implement and very cost effective to formulate using technology of PCB [1] also involuntarily vigorous whenever placed on the surfaces that are rigid, chiefly resourceful in respect of frequency, impedance, polarization and pattern, very much suited with MMIC designs Moreover when inserting the loads between the ground and patch like as varactor diodes and pins, elements with varying frequency, polarization, impedance, and pattern can, therefore, be planned.

The most important disadvantages of Microstrip Antenna are its efficiency is very low, high quality factor, has less power, scanning performance is too poor, polarization purity is too poor, spurious feed radiation, frequency bandwidth is slender. There are some applications where narrow bandwidths are required such as government security systems. When the height of the substrate is increased efficiency can also be increased (to as likely as 90%) and bandwidth (up to 35%).

1.5 Basic Characteristics

It consists of very thin patch made of metal mounted on the roof of the ground plane. Microstrip Patch is designed so that the pattern maximum is perpendicular to the patch. This is achieved by selecting the proper configuration of field of excitation beneath the surface of the patch. The patch is placed in the ground plane and is separated with the help of dielectric sheet that is called as substrate. There are lots of substrates existing that are useful in designing the Microstrip patch antennas and their dielectric constant varies in between 2.2 to 12. The substrates that are very pleasing for the high performance of the antenna are Thick Substrates and their dielectric constant varies in the range at lower side as they have the ability to yield efficiency better than others, larger bandwidth [1]. The substrates that have dielectric values higher and are alluring for circuitry of microwave as they need fields that are tightly bounded to remove the undesired radiation and coupling which will result in element smaller in size but due to the heavier losses they have very less efficiency and have moderately bandwidths that are smaller. Basic structure of Microstrip Patch Antenna is shown in Fig. 7 [1]

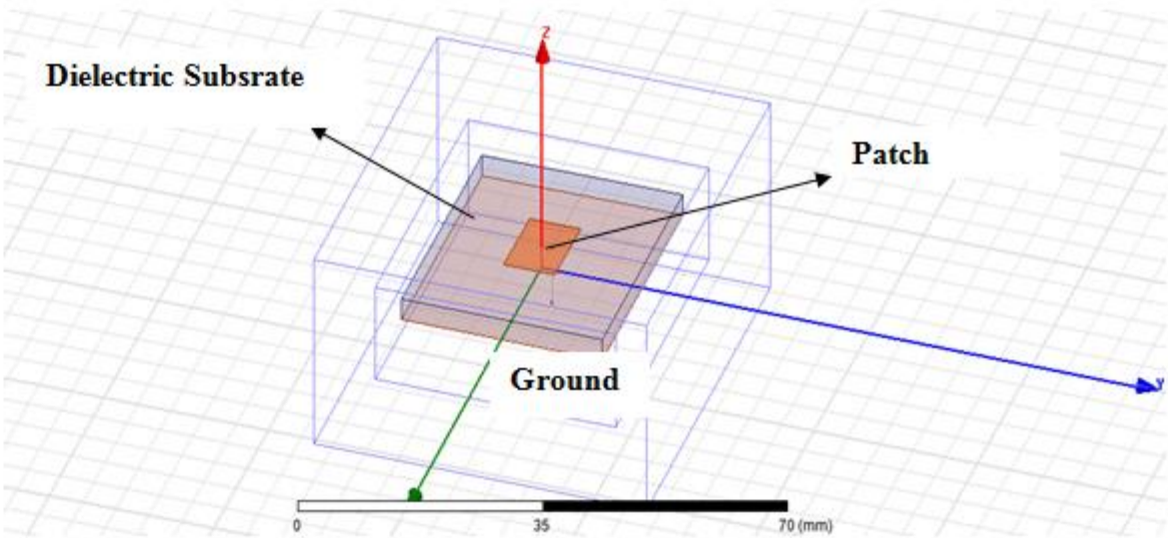


Fig.7 Microstrip Patch Antenna

Usually Microstrip Patch antennas are also referred to as Patch antenna. The Radiating elements and the feed are etched on the surface of the dielectric substrate. The patch can take the shape of square, circular, rectangle, elliptical, triangular etc. Different shapes of the patch is shown in Fig.8

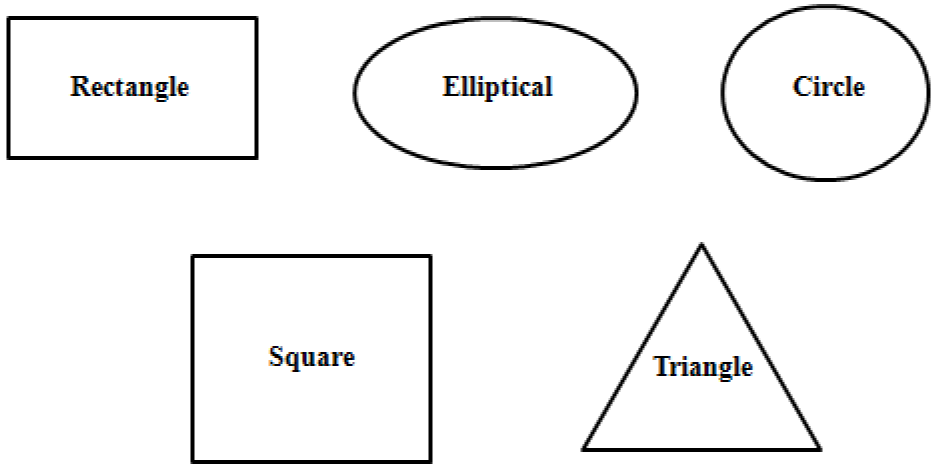


Fig.8 Patches Configuration

1.6 Feeding Methods:

Different types of configuration are available that is used to provide the Microstrip antenna with the feed. Among the entire most familiar are four and they are: Microstrip Line, coaxial probe, aperture coupling and proximity coupling.

The Microstrip feed line is usually said to be a strip that conducts and whose width is comparably smaller that of patch. This feed is very simple to fabricate and match. When the thickness of substrate increases, surface waves and radiation of feed also increases.

In Coaxial line feeds, coax inner conductor is linked to the patch and the outer conductor is coupled to ground plane that is extensively used. The coaxial probe feed is very simple and easy to formulate and match but specious radiation is very less. It is having very tapered bandwidth and is also very difficult to construct usually for thick substrates. There is drawback in Microstrip feed line and probe feed i.e. they both acquire inherent asymmetric which produce higher order modes that leads to cross-polarized radiation. For conquering these problems, aperture coupling feeds are introduced [1]. This type of coupling is the most complicated of all the feeds to formulate with very narrow bandwidth but is easier to construct and model plus moderate specious radiation. This coupling has two substrates that are divided by the ground plane. At the base in lower substrate a feed line is provided whose energy is united with the patch with the help of slot on ground plane that separates the substrates that are two in number.

1.7 Basic Microstrip Patch Properties

A Microstrip patch antenna is said to be the low profile antennas as it is much better than other antennas as it is very lightweight, easy integration, inexpensive. Fig. 9 shows the basic form of patch antenna that describes the flat plate on the surface of the ground plane. The coax conductor provides feed to the energy of couple electromagnetic inside and outside of the patch. The distribution of the electric field in case of rectangular patch excited in the primary mode is too shown.

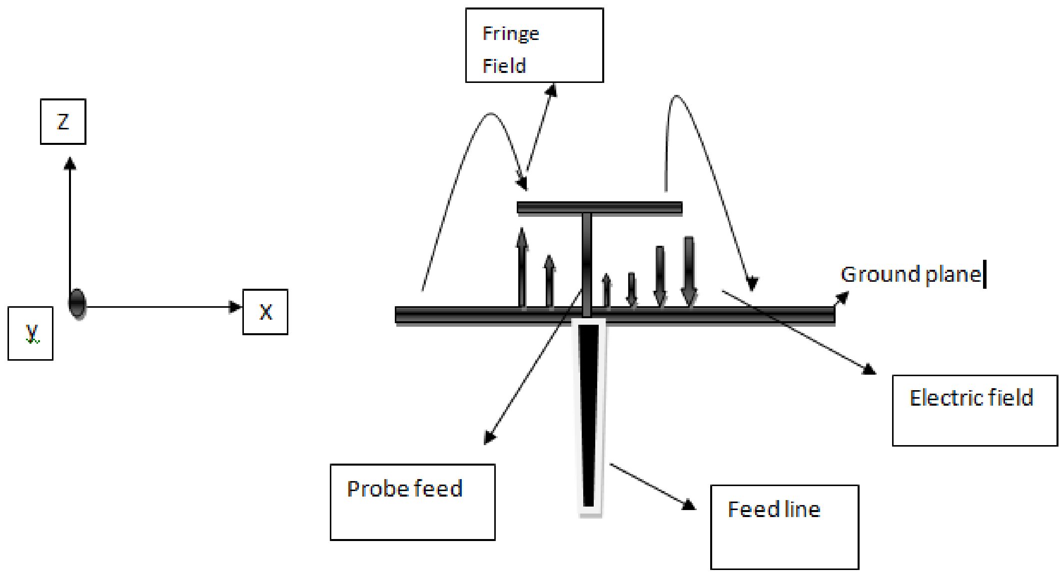


Fig.9 Basic Form of Patch Antenna

On the Patch's center the value of the electric field is zero plus at one side it is positive (maximum) and on the opposite side it is negative (minimum). Also it should be notify that the minimum and maximum will constantly change side depending on the signal phase that is applied.

Impedance Matching:

By seeing at the patches variation in both the magnetic as well as electric field, the value of current is maximum in the center and minimum close to the edges but value of electric field in the centre is 0 and maximum towards the left side, minimum towards the right side. The distribution of the current on the patch antenna is shown in Fig.10

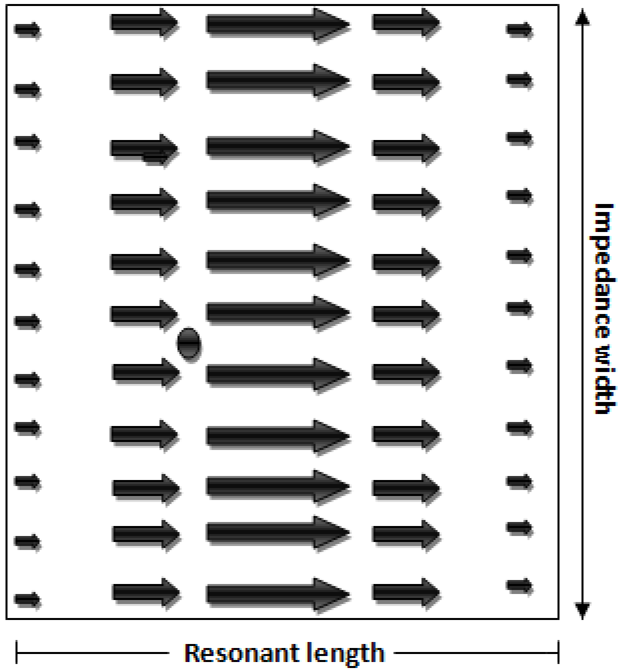


Fig.10 Current distribution of the Patch

1.8 Radiation Pattern of the Patch Antenna

The radiation pattern far-field is resulted from the patch's radiation fringing fields. The radiation pattern is used to show the antenna radiates power in a desired direction. The antenna has definite directivity expressed in dB.

The fringing fields that occur at the edges of radiation be able to be examined by the radiating slots that are mounted over the ground plane.

When estimating that the radiations occur in ½ of the hemisphere resulting into 3dB directivity. This scenario is defined as the ideal front to back ratio, where every radiation is near the front side with no radiation towards the back side. This defined ratio is particularly reliant on size of the ground plane as well as the shape. As there are 2 slots then another 3dB can be added. The slots are basically considered in order to have the length that gives the value that is equal to the impedance width of the patch and substrate height is equal to the width. These slots have generally a gain of two to three dB which gives the total gain of nearly 8 to 9 dB [1].

Whenever the patch rectangular in shape is being inserted in the basic mode it gives the maximum directivity in the direction that is normal to the patch i.e. broadside. Also when it travels away from the broadside and near to the lower level, directivity decreases. The radiation pattern in depicted in Fig.11

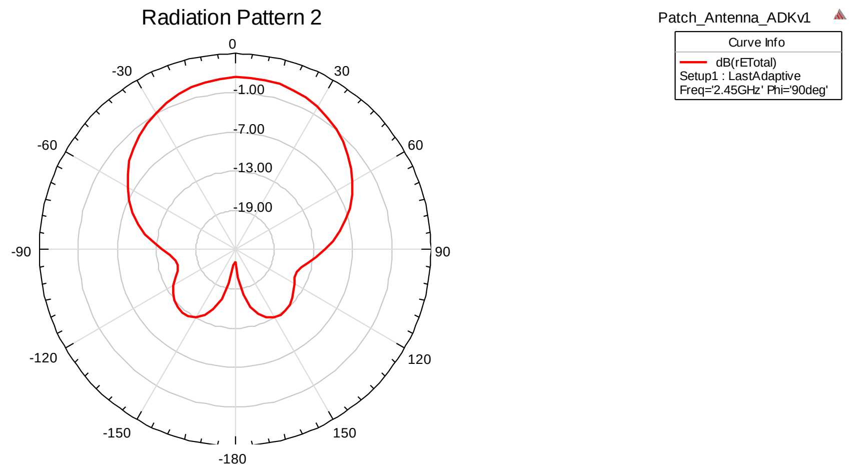


Fig.11 Radiation Pattern

1.9 Methods of Analysis

The models that are being preferred for the examination of Microstrip Patch Antennas are transmission line model, cavity model and full wave model. The simplest model is transmission line model as it provides the physical insight but the drawback is it provides less accurate results. On the other hand the cavity model is the precise one however it is composite in nature. The model which is precise, adaptable and can also care for the single elements, arrays that are finite and infinite and also gives less imminent as related to other models and is very much composite to deal with.

1.9.1 Transmission Line Model

The transmission Line model is depicted by the Microstrip antenna having the two slots with width 'W', height 'h' that is thereby divided by the transmission line with the length 'L' as presented in Fig.7. The transmission Line has not the capability to support TEM i.e. traverse-electric mode of transmission being provided that the phase velocities will be very different in the natural surroundings as well as the substrate. Quasi TEM would be the leading mode of propagation [1]. Therefore, an effective dielectric constant (ε_{reff}) is obliged to be achieved so as to report for propagation of wave in the line. The Ɛreff value is always little smaller than the dielectric constant due to the reason that fringing fields that are approximately at the boundary of the patch and are not at all restricted in the substrate of the dielectric but emanate in the air. The equation of the Ɛreff is represented as

For $\frac{W}{h} \geq 1$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (7)$$

For $\frac{W}{h} \leq 1$

$$\mathcal{E}reff = \frac{\mathcal{E}r+1}{2} + \frac{\mathcal{E}r-1}{2}[1 + 12\frac{h}{W}]^{-\frac{1}{2}} + 0.041[1 - \sqrt{\frac{W}{h}} \qquad (8)$$

Wherein,

Ɛreff = Effective Dielectric Constant

Ɛr = Dielectric Constant

h=height of dielectric substrate

W = Patch's width

As depicted in Fig.7 in which the patch that is rectangular in shape having length 'L', width 'W' placed on the substrate. To function in fundamental TM10 mode, the patch's length should be considered a smaller amount less than λ/2 where the λ is the dielectric medium wavelength and has the value as $\lambda o/\sqrt{\mathcal{E}reff}$ where the λo is free space wavelength. The TM10 mode depicts that the field changes one λ/2 cycle with the length and thereby there will be no difference in the patch's width. Fig.12 shows that the Microstrip antenna is being shown with the help of two slots that are being divided by the transmission line with length 'L' having both the ends open circuited. Because of these open ends, the voltage is maximal and the current is minimal next to the width of the patch. The fields presented next to the edges can be further determined into tangential as well as perpendicular to the ground plane.

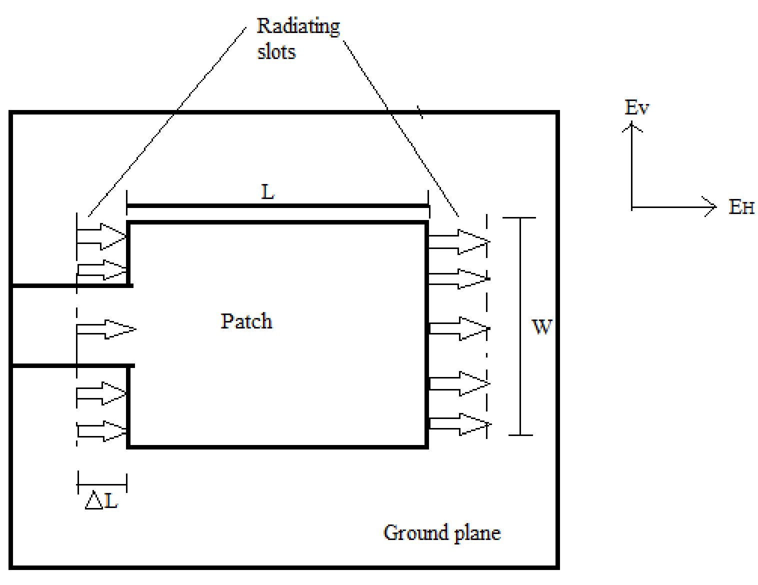


Fig. 12 View of Antenna from Top

As it is shown in fig. the electric field's normal components that are located on the edges next to the width are in the direction contrary to each other therefore, they are at out of the phase and also the patch is λ/2 long and hence they cancel each other. Similarly the component that is tangential is in the phase which implies the fields that results they get combined in order to give the maximal radiated field that is being normal to the structure's surface. Hence, the edges that are down the width are capable to be shown as the radiating slots which are two in number that are generally λ/2 apart and radiate in the half space that is beyond the plane of the ground. The patch's dimensions along the length have been inclusive on both the ends by the distance given by ΔL which is shown by Eq.9

$$\Delta L = 0.412h\frac{(\mathcal{E}reff+0.3)(\frac{w}{h}+0.264)}{(\mathcal{E}reff-0.258)(\frac{w}{h}+0.8)} \quad (9)$$

The patch's effective Length (L_{eff}) is given by:

$$Leff = L+2\Delta L \quad (10)$$

The resonance frequency is indicated by 'f_0', thus, the effective length is given by :

$$Leff = \frac{c}{2fo}\sqrt{\mathcal{E}reff} \quad (11)$$

The resonant frequency 'fo' is given by:

$$fo = \frac{c}{2\sqrt{\mathcal{E}reff}}[(\frac{m}{L})^2 + (\frac{n}{W})^2]^{\frac{1}{2}} \quad (12)$$

m and n are represented as the modes along L and W.

1.9.2 Cavity Model

The transmission line model has various disadvantages as it is popularly used patches that are rectangular in shape and also neglects the field variations down the radiating edges. These drawbacks can be removed with the help of this model. The internal area of the dielectric substrate is formed as a cavity which is being bounded by the top and bottom electric walls. The foundation for the following assumption for the thin substrates ($h<<\lambda$), because of the thin substrate the internal region fields doesn't differ in the direction of z-axis. The electric field is intended for z-direction and with the magnetic fields having the transverse components as Hx and Hy.

The lossy cavity represents the antenna along with the loss that is taken into consideration by the means of effective loss tangent δeff that is being presented by the Eq. 13

$$\delta eff = {}^{1}/_{QT} \tag{13}$$

Antenna quality factor (Q_T) is given by Eq. 14

$$\frac{1}{QT} = \frac{1}{Qd} + \frac{1}{Qc} + \frac{1}{Qr} \tag{14}$$

Where Q_d implifies the dielectric quality factor given by Eq.15:

$$Qd = \frac{WrWT}{Pd} = \frac{1}{\tan\delta} \tag{15}$$

Wherein

W_r = resonance frequency

W_T = Energy stored in the patch

Pd= dielectric loss

Qc is the conductor's quality factor that is given by Eq. 16:

$$Qc = \frac{WrWT}{Pc} = \frac{h}{\Delta} \tag{16}$$

Where

Pc=loss of the conductor

h=substrate height

Δ=skin depth of the conductor

The quality factor of the radiation (Q_r)and is given by Eq.17:

$$Qr = \frac{WrWT}{Pr} \tag{17}$$

Where

Pr = radiated power from the patch.

Therefore,

$$\delta eff = \tan\delta + \frac{\Delta}{h} + \frac{Pr}{WrWT} \tag{18}$$

The above mentioned equations give us the Microstrip Patch antenna total effective loss tangent.

1.10 Introduction to Reconfigurable Antennas:

As the demand of single wireless platform which is formed by integrating of various multiple wireless standards are increasing, the reconfigurable antennas are getting much attention. Parameters of antenna like frequency, radiation pattern, polarization are reconfigured so as to meet the requirement. The reconfigurable antennas are considered due to of its cost effectiveness and effortless fabrication and are very propitious in next centuries of wireless communication system [2]. The exceptional features are its reconfigurable capability, low cost, alteration in size that has given reconfigurable antennas the superiority to be used in wireless communication systems. Reconfigurable antennas mend their characteristics in terms of performance by correctly modifying the current flow on an antenna by the use of movable parts mechanically, attenuators, diodes, switches, active materials etc. A reconfigurable antenna can take the form of an array or a single antenna [8]. A reconfigurable antenna commonly insert a null in pattern of antenna and change the operating frequency from 2.0 to 2.40 GHz and too has the potential of transforming from left hand circularly polarized to right hand circularly polarized, so as to attain multiple goals by renewal of two or more elements. Frequency reconfigurability is commonly designed for the sake of operating at six different frequency bands that range from 2GHz to 5GHZ having its radiation pattern bidirectional. Switches like PIN diodes or varactor diodes are chiefly used to obtain reconfigurability. Though the decrease in the electrical size of antenna that makes a single wideband antenna unrealizable due to limitations on the bandwidth. However separate as well as different antennas for different operating frequency are not practicable, but single frequency reconfigurable antenna can obtain this. By this way it came into reality and is ideal for satisfying requirements of multiband antenna. Lately reconfigurable antennas have aggregated a heavily amount of interest in research for applications like Cognitive radio, radar system, cellular radio system, satellite communication system. It has also been supporting a huge number of standards such as Wi-Fi, WiMAX, LTE, etc. The layout of reconfigurable antennas is shown in Fig.13

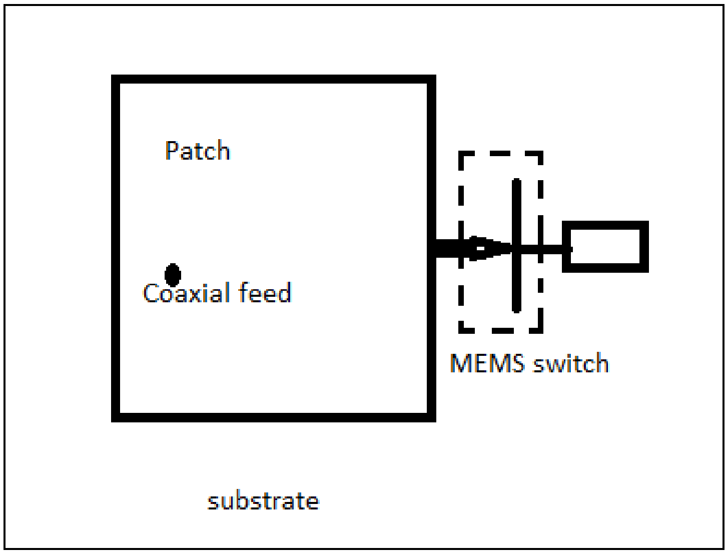


Fig.13 A layout of Reconfigurable Antenna

1.11 Reconfigurable Antenna Types:

Primarily three basic types of reconfigurable Antenna are there: Frequency, Polarization and Pattern.

1.11.1 Frequency Reconfigurable Antenna

These antennas are capable of reconfiguring the operational frequencies with roughly the fixed radiation patterns. This sort of antenna is applicatory for frequency agile or multi-frequency systems. Whenever rectangular patch antenna is loaded on the non radiating edges will permit it to operate at different frequencies whenever the intensity of loaded slots is altered as shown in Fig.14.Therefore,Reconfigurable patch antenna is also used for multiband applications[14] .Nearly 6 to 8 switches have been installed in the slot. The distance among all the slits is'd'. By regulating the switches in various configurations; antenna is reconfigured and regulates its operational frequencies from 0.6 GHz to 1.2 GHz.

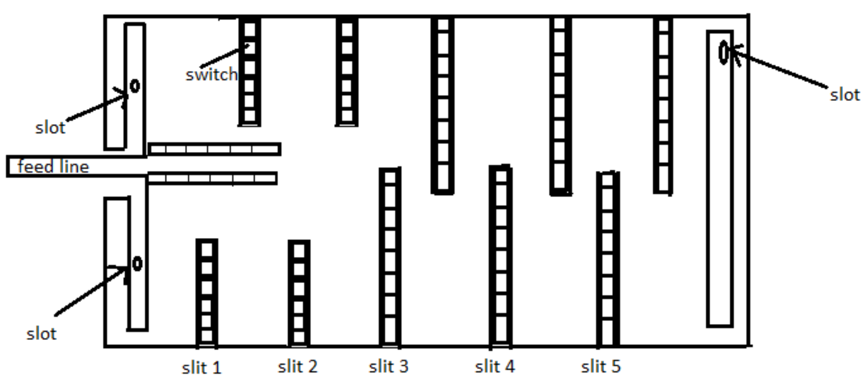


Fig. 14 Frequency Reconfigurable Antenna

1.11.2 Pattern Reconfigurable Antennas:

This type of antennas provides the copious radiation patterns at the same operational frequency. They have the tendency to modify the characteristics of radiation pattern like polarization, antenna gain, etc by altering its physical configurations [19]. These antennas also have the tendency to avoid noise from the outdoor environment, enhance the security, and also save energy by regulating the signals to the dedicated users. In pattern reconfigurable antenna, polarization changes along with the radiation pattern. They emend the performance of the system by using the numerous paths like switched combining, loop slots as shown in Fig.15 [14]. In this Fig, A reconfigurable antenna that has loop slots has the tendency to shift the radiation pattern while maintaining its operational frequency. 12 switches are positioned on right side besides on the loops left side. They operate in two states where in State 1, all the switches that are on the left side will be switched off and right side is switched on. Likewise, in State 2, all the switches that are positioned on the left side are turned on and on the right side are turned off. By the use of these states different radiation pattern can be obtained thereby providing the pattern reconfigurable antenna.

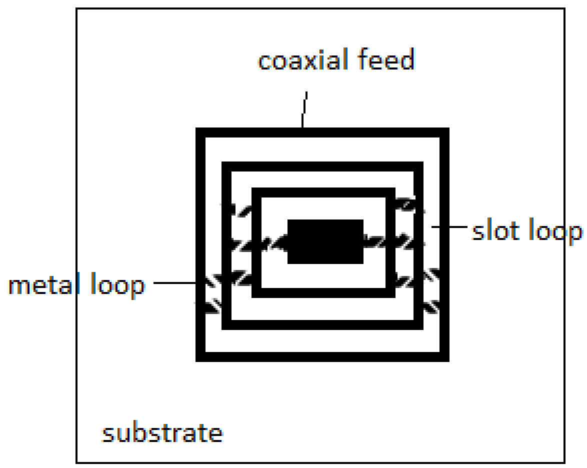


Fig.15 Pattern Reconfigurable Antenna having slots

1.11.3 Polarization Reconfigurable Antenna:

Polarization can be varied electronically in this type of antenna. Basically there are three different ways by which it can be achieved: by emending the current distribution of an antenna, by altering the path of the current of the antenna, by using the reconfigurable phase shifter in order to control the phase. This antenna is very much proficient of switching into different modes of polarization like as Linear Polarization (LP), Left hand (LH), Right Hand (RH), and Circular Polarization (CP). They have tendency of lending polarization diversity. Whenever these antennas are having polarization diversity they can very well use the theory of frequency reuse in order to increase the response of communication systems, and is serviceable only when the frequency band is limited[20][21]. Polarization reconfigurable antenna with loop slot is shown in Fig. 16 which is adequate enough to switch to different modes of polarization. In this Fig, there are two pin diodes namely P1, P2 that has been loaded on the loop slot. LHCP will result when diode P1 is turned off and P2 is turned on and likewise RHCP will result when P1 is turned on and P2 is turned off. Similarly Linear Polarization will result when both the diodes are either on or off.

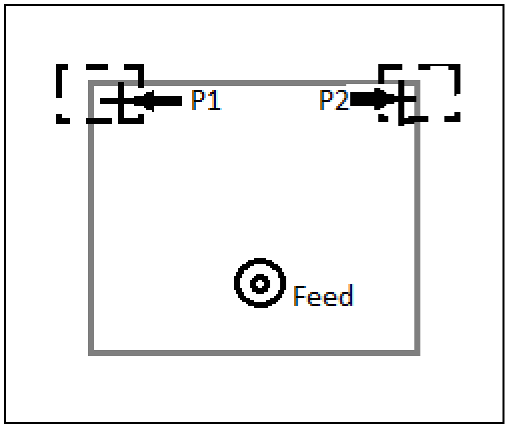


Fig. 16 Polarization reconfigurable Antenna

1.12 Antenna Technologies for Reconfigurable Antenna:

As it is known that reconfigurable antenna is recently showing a lot of potential in the research area for numerous applications such as radar systems, satellite communication, airplane etc. With this, reconfigurable antenna also supports a numerous standards such as Wi-Fi, WiMAX, WLAN, etc. so as to handle the surroundings of the environment [6] [3].

There are two different approaches so as to obtain the antenna array frequency suppleness:

1.12.1 Reconfiguration at Element Level: Antennas are integrated with the electronic switches (PIN diode, MEMS switch), tunable materials (varactor diodes) [4] [7] and mechanical actuators for the purpose of reconfiguration.

a. RF switches: It either opens or closes the path for the flow of the current on the reconfigurable antenna. A reconfigurable antenna can be fabricated by connecting antenna parts with RF switches. Some of the characteristics of the switches are characteristic impedance, bandwidth. A switch has the ability to perform in dual way like: when it is on, it acts as resistor (R_{on}) and when it is off, it acts as Capacitor (C_{off}) [9]. Frequency reconfigurability in the antennas can be attained by the help of MEMS, or PIN diodes [10] [15]. Cut off frequency of the switch is given by Eq.19

Cut off frequency of the switch is:

$$fc = \frac{1}{2\pi(Coff)(Ron)} \tag{19}$$

Switches are basically utilized for reconfiguring Microstrip patch antennas as is shown in Fig.17. Patch sides are interconnected with RF switches so as to build up.

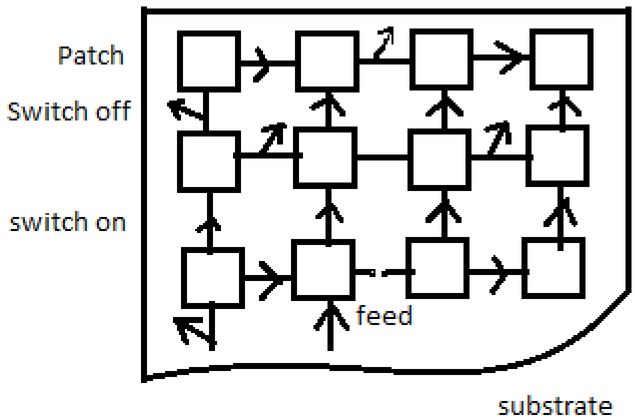


Fig. 17 Reconfigurable Patches

b. Tunable Materials (Varactor Diodes): Varactors are imported for the purpose of tuning of frequency range of the antenna. Alternative way so as to achieve frequency suppleness is by introducing the varactors in the design of the antenna [11] [13]. There is a resonating Microstrip radiator that comprises of patches that are small which are interconnected by varactors is provided. If a varactor having suitable biasing is used as in Fig.18, the electronic tuning by varying the DC voltage is achieved [12]. It is a trending area of research but still faces a lot of challenges such as reliability and efficiency [18]. Loading the varactor in the design of antenna will provide a tunable capacitance which is having the resonant frequency as shown in Eq.20:

$$fr = 2\pi\sqrt{\frac{1}{LC}} \qquad \textbf{(20)}$$

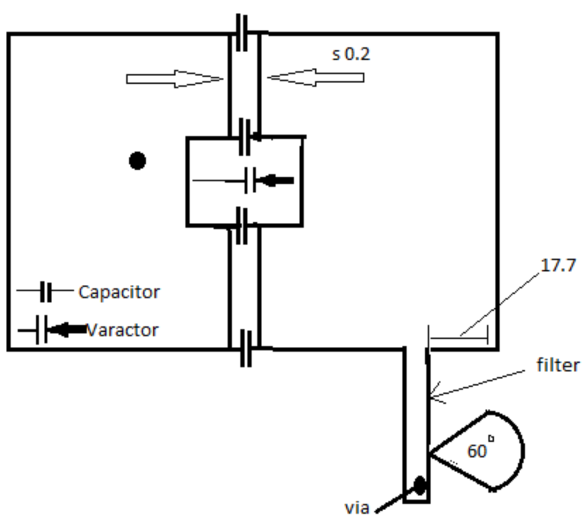


Fig.18 Varactor Diodes loaded with biasing circuit.

c. Using mechanically reconfigurable antennas:

There are many places where RF switches cannot be used just because of power losses and also complexity of the biasing circuit, then these mechanically reconfigurable antennas came into existence [17].

1.12.2 Wide Band Antennas:

There is one more possible way that is to use the ultra wideband or multiband antenna elements. For this the need of antenna solutions which incorporate the good performance e.g. gain and radiation pattern intended for the bandwidth and also the tunable filter that is being provided to choose the operational band of frequency. There are many designs of antenna utilized for broadband that is used for several applications have been granted. For example, Transversal Electromagnetic horn or dielectric filled wave-guide antenna that have the capability to offer broad bandwidth having the radiation pattern that is directive. There are Vivaldi antennas that are end-fire antennas [4] and LTSA that can be used for phased array. Dual polarized Vivaldi antenna arrays can also be intended for nearly more than 10:1 bandwidths whilst scanning 45° or more. The illustration of this design approach is given by reconfigurable Vivaldi antenna in which a BPF is predetermined in the feeding line of radiating structure which results in a switchable frequency antenna and also the varactor diodes are inserted inside the structure of the filter so as to provide frequency reconfiguration capability.

1.13 Design of the Reconfigurable Antenna:

The schematic layout of antenna has been shown in Fig.12. To design the reconfigurable antenna, the necessary parameters that are required to take in consideration are: ground plane, substrate, type of the patch (Microstrip patch, Microstrip slot patch), Feed (coax feed, aperture feed, proximity feed), frequency.

1.13.1 Ground Plane: A conducting surface that is electrically connected to the ground. It functions as a most important and the basic part of the antenna in order to reflect the radio wave that emerges out from the other elements of the antenna. In ground plane, its conducting surface must be at least one-fourth of the wavelength of the radio waves that also makes up the other half of the antenna.

1.13.2. Substrate: There are plenty of substrates that can be utilized in making of the reconfigurable antenna. Some of the various substrates are shown in Table1 [22]

Table1. Various substrates along with dielectric constant

SUBSTRATE	**DIELECTRIC CONSTANT(Ɛr)**	**RESONANCE FREQUNECY**	**GAIN**
FR-4	4.4	5.8 GHz	9.8
Roger 4350	3.48	2.586 GHz	4.62
Benzocyclobutane	2.6	2.04 GHz	5.5
RT Duroid	2.2	10 GHz	12.03

1.13.3 Patch: There are different patch and some of them are Microstrip patch, Microstrip slot patch, printed dipole patch. As illustrated in Fig.19, a Microstrip antenna through the transmission line which is having the ground plane mostly made up of copper (high conducting metal). The patch having length 'L' and width 'W' rests resting on the top of substrate.

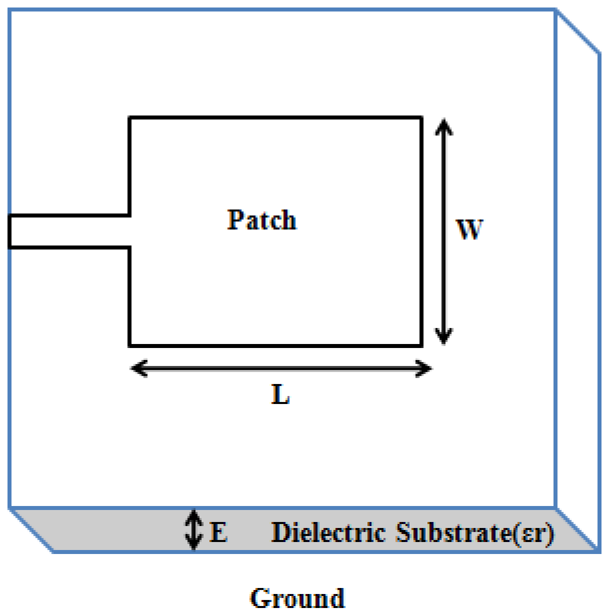


Fig. 19 Microstrip Patch Antenna

The patch Antenna frequency is given by length ‘L’ and is given by the Eq. 21:

$$fc = \frac{c}{2L\sqrt{\varepsilon r}} \tag{21}$$

1.13.4 .Feeding Techniques: There are numerous feeding techniques that are being provided during the reconfigurable antenna design. Some of them are proximity coupled; aperture coupled, Microstrip feed, coaxial feed, etc. In Microstrip feed, there is a strip that is conducting and is directly associated with the edge of the patch as shown in Fig.20

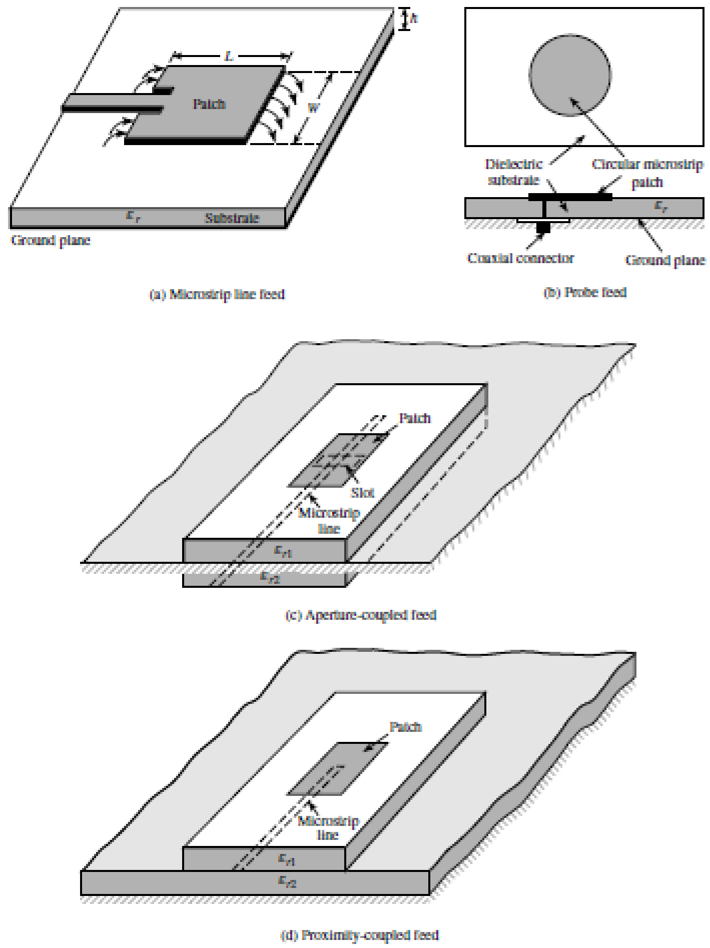


Fig.20 Feeding Techniques [1]

Chapter 2

LITERATURE REVIEW

2.1 Introduction:

The advantage of Reconfigurable Antenna is to generate better radiation patterns with greater bandwidths when compared to patch antennas. Additionally antennas with required reconfigurability can be achieved by using the combination of both strip conductors and slots that are arranged down the sides of the Microstrip feed and probe feed. Whenever designing the small size antenna there is always a compromise between the size, efficiency and the bandwidth. Architecture of Reconfigurable antenna efficiently makes use of restricted area by combining multiple functions in one single antenna. Therefore, it will result in the reduction of area that is being occupied by different and multiple elements of antenna resulting in amplified performance and functionalities.

Jian Ren et al [2], presented a pattern reconfigurable antenna by the application of periodic structure which is unique and finite. The H-shaped structure is set equally on both sides of the dipole in order to direct the flow of power in the end-fire direction. By the use of PIN diodes in between the H-shaped structures, different radiation patterns are being formed by varying the state of PIN diodes. The proposed antenna resulted as end fire mode having front-to back ratio as 15dB which is high and also pattern reconfigurability is achieved in the frequency band ranging from 2.47 - 2.9GHz.

Ahmed Khidre et al [3], come up with new design for the microstrip patch antenna so as to obtain reconfigurable dual band operation with the frequency ratio that is tunable. The said design makes use of lumped capacitor that is placed in the middle of the patch, which will results in two resonating frequencies. Also, so as to obtain electronic tuning, varactor having the appropriate biasing is used by varying the DC voltage. The design results in frequency ratio ranging from 1.45-1.93 by varying the capacitance value from 0.31-0.74 pF corresponding to voltages 0-30V.

Nurulazlina Ramli et al [4], presented a reconfigurable microstrip antenna incorporated with the technique of aperture coupling which has the advantage of reducing counterfeit radiation pattern so as to increase gain as well as the bandwidth. This design introduces a new theory for achieving frequency reconfigurability. Firstly, four switches of PIN diodes named as Switch A are used so as to trigger the aperture slots on the ground, that results in two operating frequencies 2.6 or 3.5 GHz. In the meantime additional four switches of PIN diodes named as Switch B that are placed on L-stub elements are used so as to turn on the capabilities of patterns. With this antenna's beam angle can also be controlled with Switches C and D that are operated alternatively so as to activate radiating patches (either two upper or two lower patches). Antenna also has the capability to vary the patterns with the six cases of switches having the beam located at $+32^0$, $+3^0$, or -1^0 operating at 2.6GHz or at $+28^0$, $+23^0$, or -24^0 operating at 3.5 GHz.

Y.Tawk et al [5], presented a fresh technique for reconfiguration so as to implement frequency-tunable filters (bandpass). This technique is being obtained by varying the total capacitance value of the filter by means of incorporated varactor inside its structure. Additionally, the reconfigurable bandpass filter is then integrated inside the feeding line of antenna which is printed so as to outline one structure. The combination of these two leads to the tuning of operating frequency of the antenna without the use of active components as well as biasing lines on the radiating surface of antenna. The proposed combination of antenna and filter having filtering ability with preserving the performance of the radiation called as “filtering antenna” or filtenna.

S.Danesh et al [6], presented a compacted frequency reconfigurable DRA (Dielctric Resonator Antenna) for the applications of LTE/WWAN and WLAN. The presented antenna gives the frequency tuning in between the range of 1.60 and 2.71 GHz. The said design has four dielectric resonators that are identical and rectangular having permittivity of 10 each with the three p-i-n diode switches that are positioned on the feedline network between these resonators. The size of the antenna is taken so as to support the mobile devices. The proposed antenna results in four single-band modes having the impedance bandwidth of 17%, 11%, 14% and 6%.

Matthew W.Young et al [7], presented a miniaturized antenna that is dual varactor-tuned with a single bias bring out through the use of RF feed. Large tuning range is been obtained by the dual varactors i.e. 410-990 MHz, 2.1-3.5 GHz, VSWR =2:1. Also the single bias voltage simplifies the network of bias. With the bias via RF feed eradicate the requirement for separate bias lines, resulting in decreased electrical size of antenna through tuning. The above proposed design basically focuses on limitations of radiation efficiency that is being related with the planar structure for small size antenna having the need for wide tuning range.

Ghanshyam Singh et al [8], presented an antenna design for achieving frequency reconfigurability for wireless devices. This design consists of a rectangular patch antenna having slot that is square in shape that use two PIN diodes at the 10GHz frequency and reconfigurability is obtained in the range of 10-10.5GHz. By switching the diodes states as on and off frequency reconfigurability is being obtained. For the ideal case the diodes are replaced by microstrip-line for the on-state. The substrate being used is FR4 having thickness of 1.6mm.

Kagan Topalli et al [10], presented dual frequency rectangular slot antenna with the use of RF MEMS technology. In this design antenna tuning is attained by the use of RF MEMS variable capacitors on the stub. This design results that antenna resonance frequency have the capability to be tuned in 1GHz range that too in X-band.

Chandrappa D.N et al [11], presented frequency reconfigurable antenna with single feed .The structure of the antenna comprise of rectangular patch being loaded with slots that are placed horizontally having the slot arms that are extended. By loading the varactor diodes over the slots and by changing the effective length of the slots, the tuning of resonant frequencies is being observed. For the frequency that is operated at the lower side total size reduction of 84% is obtained when related to traditional microstrip patch. This antenna is required for the applications like as GSM, WLAN etc that operate at wide range of bands.

Abdelnasser Eldek et al [12], proposed a design that comprise of microstrip-fed dipoles through the balun that is being simplified. Antenna operating frequency as well as the mode of operation can be changed by regulating the length of dipole by connecting or by disconnecting slots. The proposed antenna supports two modes: Multiband, Broadband.

Shaoqiu Xiao et al [13], presented revised phased array with the use of elements of pattern reconfigurable antenna so as to get the wide angle scanning performance having low gain fluctuation. The radiation pattern reconfigurability from the element is implemented by tuning the value of the capacitive reactance of the varactors. In this proposed design, five elements are set in uniformly spaced linear array. The results shows that the main beam of array have the ability to scan from -70^0 to 70^0 in the H-plane with the fluctuation in gain merely less than 2dB.

Wang Bing Zong et al [14], presented some of the researches being carried on Reconfigurable antenna ever since 2001 in China at CEMLAB (Computational Electromagnetics Laboratory). Various forms of reconfigurable antenna are being introduced which can apprehend frequency, pattern and polarization reconfigurability by controlling electrically.

Daniele Piazza et al [15], presented new array technique for reconfigurable antenna for the purpose of MIMO for improving the capacity of link in space closely related to antenna arrays. This design system comprises of two printed dipole array that are being divided by the quarter wavelength distance. Every single dipole has the ability to reconfigure in length by the use of PIN diode switches. When switches are configured it affects the mutual coupling within the elements of array with the radiation pattern directing towards different forms of pattern diversity so as to improve the capacity of link. Basically in this paper comprehensive applicability is being presented analogous to conventional half wavelength printed dipoles. The results show that an average improvement of 10% and 8% is nearly obtained in capacity of the link for Signal-to-Noise Ratio corresponding to 10dB and 20dB respectively in the internal environment when compared to system using non reconfigurable antenna arrays.

M.-J. Lee et al [16], presented frequency reconfigurable antennas for the applications of cell phones. The presented design is totally based on traditional PIFA having two stubs being integrated with the varactor diodes. So as to attain the characteristic of wideband, the two resonant frequencies (f1 and f2) obtained first are controlled independently by changing the capacitance value corresponding to voltages being supplied. Alternatively, studies that are parametric have been also conducted for the length of antenna with its capacitance. The design depicts that the antenna has a tunable bandwidth which is given by VSWR<2.5 of 45.7% (606MHz~965MHz) with 47.5% (1343MHz~2181MHz) at frequencies f1 and f2 respectively leading to f1 covering the LTE,CDMA,GSM and f2 covering DCS,PCS,WCDMA bands. The gain obtained at f1 varies from -4.3dBi to -1.5dBi and f2 varies from -6.4dBi to -2.7dBi.

Y.Tawk et al [17], presented a novel system design for antenna for the applications of cognitive radio. The structure of the antenna comprises of a UWB antenna and a system for frequency reconfigurable antenna. The UWB antenna is used to scan the channel so as to discover bands whilst tuning the section of reconfigurable so as to enable communication in between these bands. The frequency reconfigurability is achieved by the rotational motion of the patch of the antenna, which is regulated by the use of stepper motor which is placed on the back of structure of antenna. Stepper motor is driven with the help of NPN Darlington array.

Yevhen Yashchyshyn et al [18], presented a waveguide slot antenna having the reconfigurable aperture for which the solutions are focused on material of semiconductor which is used to design the electronically reconfigurable antennas. Surface PIN (SPIN) diode is the major element of the reconfigurable antenna of whose conductivity varies proportionally to the density of plasma. Different shapes of radiation pattern are generated by selectively activating the SPIN structures.

Esmail Nasrabadi et al [19], presented a new pattern reconfigurable antenna with the use of circular patch at the centre with the four parasitic patches. Three modes are formed by the radiation pattern of this design. Mode of antenna is changed is completed by the use of four PIN diode switches that are positioned in the spaces (or gaps) of rectangular patch that is parasitic. An open or short circuit is provided in the space by the simple electrical arrangement. This antenna results in 5.7 GHz frequency.

T.Debogovic [20], presented the new reconfigurable antenna design explaining about the perspective of the reconfigurable antenna in a communication system and also the overview of the mostly used switch as well as tuning elements that will activate reconfiguration of antenna.

Xue-XiaYang et al [21], presented a microstrip patch antenna that is reconfigurable having polarization states switching amidst linear polarization (LP), left-hand as well as right-hand (RH) circular polarization (CP). The waves of circular polarization are agitated by two loop slot elements in the ground plane. To modify the direction of current a p-i-n diode is being placed in on every slot so as to determine the state of polarization. The experimented bandwidth of -10dB return loss for left hand circular polarization (LHCP) and right hand circular polarization (RHCP) are about 30MHz and 60MHz respectively. Gains for the operation of CP are 6.4dB and for LP is 5.83dB. This obtained reconfigurable patch antenna with having agile polarization is used for 2.4GHz wireless systems for communication.

Mike W.K Lee et al [23], presented a normal patch antenna that is being casted as resonance LC parallel circuit which indicates that resonant frequency can be lowered down if the patch consists of slots so as to increase the value of inductance L without merely affecting the capacitance connected in parallel. This paper proposed a new design for miniaturizing i.e. a patch with C-shaped slots (four in number) for two polarizations. The proposed antenna is being shortened to $\lambda_0/8$ size. It results in two polarizations with the bandwidth of about 6.9%. So as to enlarge bandwidth, the T-probes are being used to feed the 4-C slot-cut patches. Miniature size can be maintained by replacing the stubs of the T-shaped proximity feed by the lumped components. This antenna design has a low radiation efficiency of about ~20% so it provides a solution for low-cost that is mostly used for the applications of short-range two-way communication.

Rifaqat Hussain et al [24], presented a frequency reconfigurable antenna system for MIMO (multiple input multiple output), multiband. The elements of antenna are incorporated with an UWB sensing antenna so as to establish an entire platform for antenna for the application of Cognitive Radio (CR). Also the dual-element antenna for MIMO is incorporated varactor diodes and p-i-n diodes for achieving the frequency reconfigurability. For the antenna system for MIMO two modes of selection are used with the varactor tuning so as to compass the frequency over a wideband specifically below 1GHz. The results simulated from this antenna is used to envelop a broad range of frequencies ranging from 720~3440MHz.

Hsiao-Yun Li et al [25], presented a slot-loop antenna incorporated with TMN for the frequency reconfigurability. This antenna is intended by encumbering ferroelectric varactors along a slot loop. This antenna is fed with a coplanar line instead of microstrip line so as to hold the advantage of being it as a unipolar. We make use of TMN as it is very difficult to obtain a good matching above the wide bandwidth. TMN is realized with the use of varactor in series and it does not increase the antenna size. The result shows that by changing the bias of the FE varactors from the value 0V to 15V, the frequency can be tuned from 6.71 to 9.14 GHz. Also the return loss is greater than 20dB in the proposed technique.

Huseyin Altun et al [26], presented a reconfigurable fractal antenna for the purpose of multiband applications. In this paper fractal antenna is fed with 50ohms coax that is round from the middle.

The distinctiveness of antenna varies by making the PIN diodes in off or on state that will vary the operation frequency and the radiation pattern. The presented antenna varies shows the frequency ranging from 1.51 GHz to 8.6 GHz.

Preet Kaur et al [27], presented a new technique by introducing fractals in the reconfigurable antenna for the multiband applications. In this paper it is shown that how fractal antenna designs support the requirements of cost effective, miniaturization as with the increasing demand in communication technology there is demand of such requirements. Also with this, fractal antenna's performance can be improved by the concept of reconfigurability. This paper combines both the advantages of reconfigurable and fractals.

K.J. Vinoy [28] presented some of the concepts of fractals for the design of antenna. The author describes that geometries of fractals have many good and interesting properties that can be used to build up so many practical antenna for the applications of wireless. These antennas have the capability to reduce the size and also have multi-frequency characteristics.

Chapter 3
OBJECTIVES OF THE THESIS

The main objectives of this thesis are:

a. Analyze the different parameters of antenna for multiband and reconfigurable applications.
b. To implement fractals for multiband operations as well as for miniaturization of the antenna.
c. Design a reconfigurable antenna incorporated with the fractals and varactor diodes for multiband operations along with the switching capability.

Chapter 4
SCOPE OF THE THESIS

The field of designing antenna is getting more attention because of the development in the wireless communication. During the ancient time, at the period the radio frequency was invented, simple design of the antenna was used as a resource so as to transmit the waves via air. Guglielmo Marconi was the first inventor who invented wireless telegraphy system and given birth to wireless technology in the year 1894. Development in the antenna pays a very important role in wireless communication seeing that number of users is increasing day by day in the field of telecommunication. Due to increase in number of users may heads to block the existing spectrum of local area like WLAN, WPAN etc. Hence, the advancement of concept reconfigurable antenna is very fascinating for the future wireless communication system as they have the ability to provide users with a single antenna to be used in various other systems. Also with this, when the concept of Fractals is being clubbed together that leads to reduction in size, multiband applications, the antenna becomes more fascinating for the applications of wireless communication.

There are many advantages of reconfigurable antenna as they have the ability to change the parameters of antenna according to the required operation. Reconfigurable antenna mostly relates to the microstrip patch antenna with their incorporation with the switching device which will add advantage of microstrip antenna as low cost for fabrication, light in weight, having low profile and is very much suitable with all the integrated devices. The reconfigurable antenna has the switching ability and is done by the help of PIN diodes, MEMS switches, Varactor diodes, RF switch.

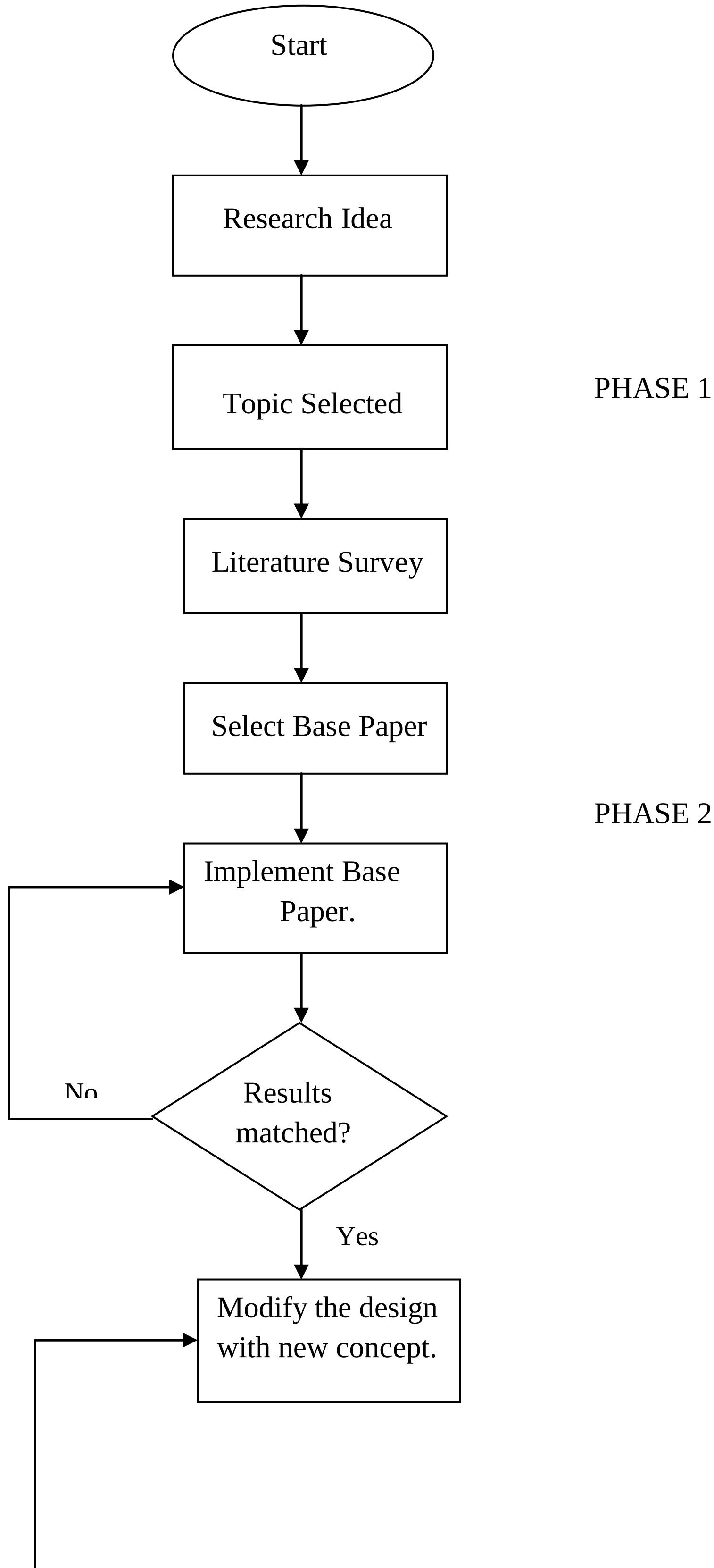
A single function antenna can be replaced by a single multi-function antenna that can be done with the help of reconfigurable antenna which in turn reduce the complexity, total cost and size thereby improving the total performance of the antenna. As with the fast growth in the communication field, reconfigurable antennas are attracting towards itself as in this single antenna is sufficient so as to fulfill the demands of users. There are much more benefits of using reconfigurable antennas when compared to the conventional antennas as they have the fascinating characteristics that provides many functionalities e.g. Reconfigurability in terms of Polarization, Frequency, Radiation Pattern. The useful application of reconfigurable antenna is associated with the operating frequency because it is the easiest feature that can be change.

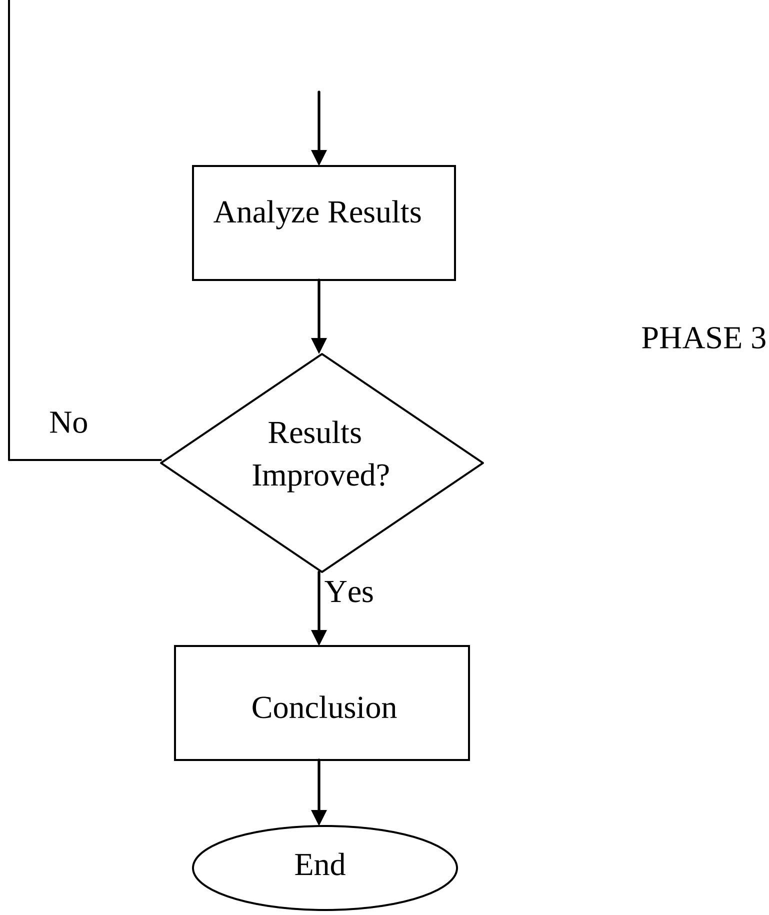
Varactor Diodes are being used as a switching element to obtain reconfigurability so as to achieve the frequency tuning faster. Application of Varactor diode is that it provides electronic tuning and also it provides service that is reliable. Along with this, they provide a mechanism of changing the capacitance value with the circuit by varying the voltage value or by controlling the voltage.

The Fractal term basically means using the same geometry again and again i.e. it describes the family of shapes (it can be any shape) that has self-similarity in its geometrical structure. There are many examples of fractals in the surrounding environment such as trees, leaves, clouds etc. Basically the concept of fractals is being introduced in the design of the antenna so as to provide the multiband characteristics.

Chapter 5
RESEARCH METHODOLOGY

The whole process by which the research work has been carried out is being shown with the help of flow chart as shown below.





The flowchart gives us the idea about how research work is being carried out. The summarization is as follows:

PHASE 1

In this very phase, the idea we have with us we explore the idea and search the topics related to that idea and then we select the desirable topic and do the detailed survey for that topic.

PHASE 2

In this phase after the literature survey, we select the paper in which we want to carry our dissertation and then we implement that paper until our results are matched.

PHASE 3

This is the final and most important phase of the dissertation. In this phase we modify the design according to our ideas and thoughts and analyze it until we get the improved results as compared to Phase 2.

Chapter 6
IMPLEMENTATION OF BASE PAPER

The selected base paper is 'The Patch Antenna with the Varactor-Loaded slot for reconfigurable dual-band operation.'In this paper new strstegy for the microstrip antenna so as to attain the dual band operation incorporated with the tunable frequency is presented. This paper involves two models to attain the dual-band operation. In the first model, a lumped capacitor is used in the center of the patch antenna which will hence result in two resonant frequencies. The two frequencies that are obtained and their ratio are therefore the functions of value of capacitance. The second model uses the varactor with an proper biasing, which results in electronic tuning by varying the DC voltage[3]. HFSS is used to carry out the results. In this frequency ratio of 1.45 to 1.93 with the capacitance range of 0.31 to 0.74 corresponding to the voltages 2V to 30V is achieved.

6.1 Implementation of Models:

6.1.1 Model 1:

A probe feed patch antenna with capacitor in the middle of the patch is taken. The substrate used is Rogers RT/duroid 5880 having dielectric constant Ɛr = 2.2. The capactor is inserted in the middle of the patch so as to control the current path length on the surface of the patch. Capacitance value is taken to be 0.5 pf that results in two resonant frequencies i.e f1= 2.275GHz and f2=3.95GHz but the original resonant frequency that is obtained with the slot and the capacitor is 2.45GHz [3].

6.1.2 Simulated Results:

6.1.2.a Return loss-

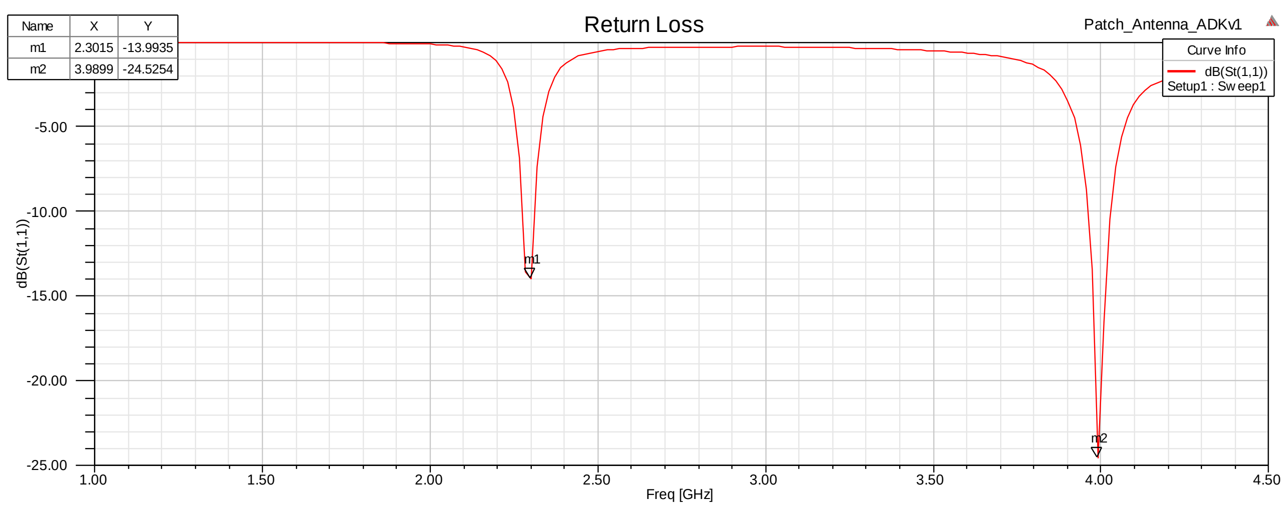
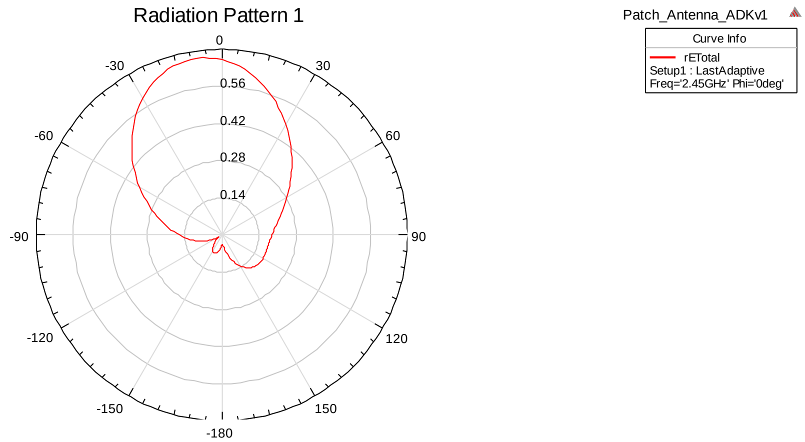


Fig.21 Return Loss for the Model 1.

6.1.2.b Radiation Pattern:

For E Plane :



For H Plane:

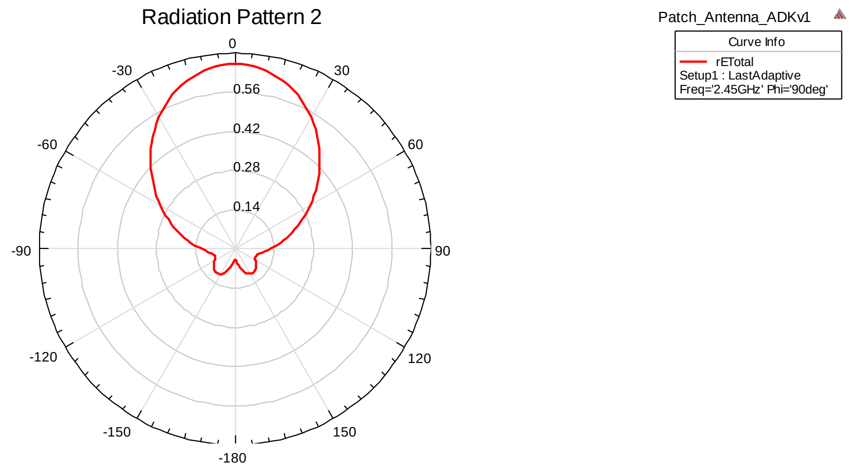


Fig.22 Radiation Pattern for E-Plane and H-Plane of Model 1

6.1.2.c Gain

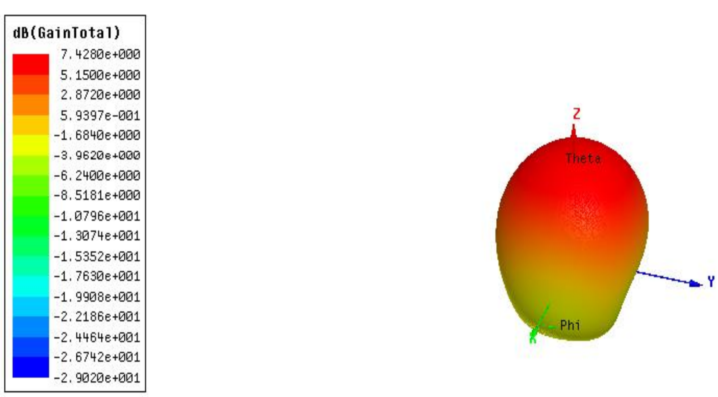


Fig.23 Gain of the Model 1

6.1.3 Results

Table 2. Results in Tabular Form

Gain	7.428 dB
Freq	2.45 GHZ
Directivity	5.6536
Peak gain	5.5309
Peak realized gain	1.0455
Front to back ratio	258.06
Radiation efficiency	0.97831
Lower band freq/ Higher band freq	2.30/3.964

6.1.4 Model 2:

In this model varactor diodes are introduced with the appropriate biasing in the place of the capacitors. A varactor (SMV 1430) is used in this model which provides the tuning range of 0.31≤C≤1.24 pF with 30≤Vdc≤0V. This model provides the tuning range from 1.45 to 1.93.

6.1.5 Simulated Results of Model 2:

6.1.5.a Return Loss:

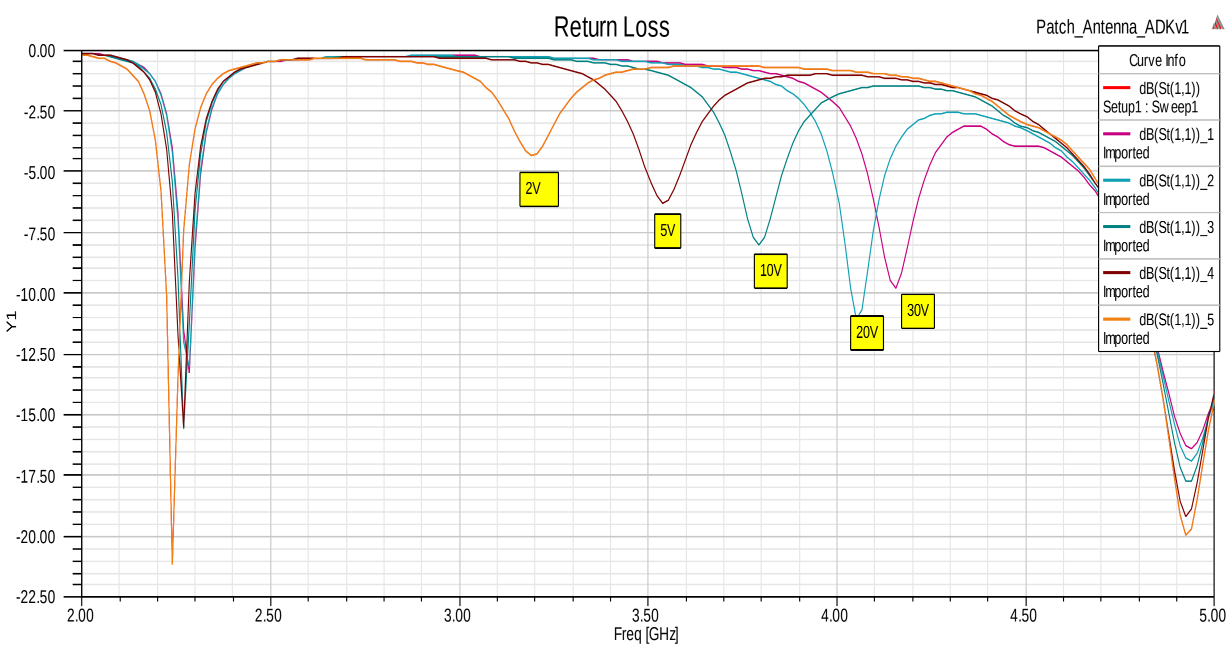
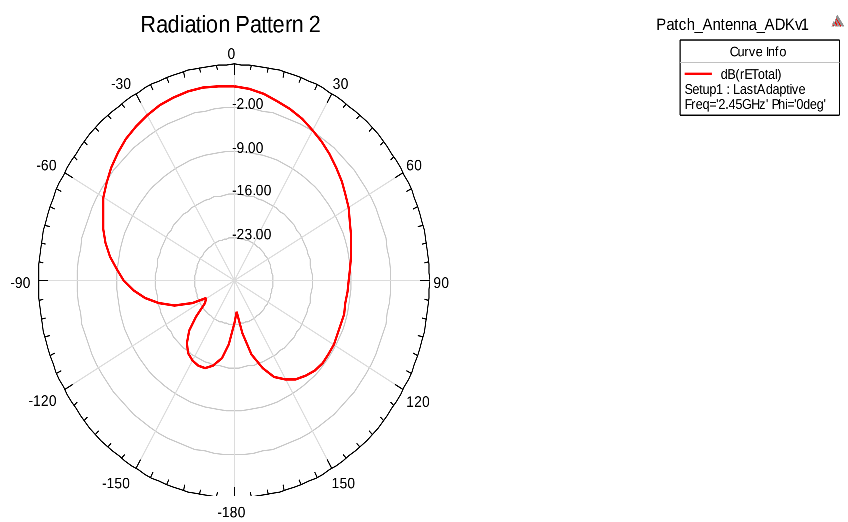


Fig. 24 Return Loss for the Model 2

6.1.5.b Radiation Pattern

For E Plane:



For H Plane

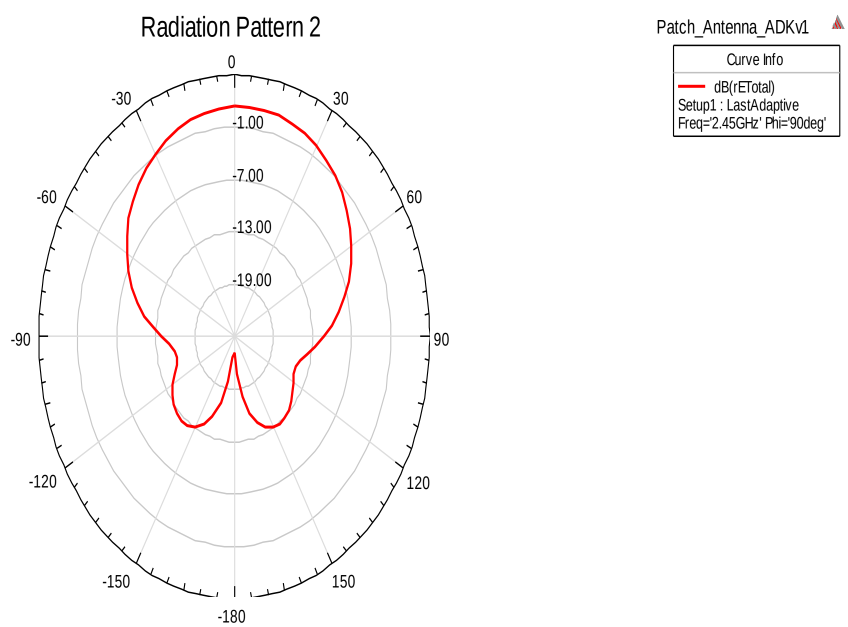


Fig.25 Radiation Pattern for E-plane and H-plane of Model 2

6.1.5.c Gain:

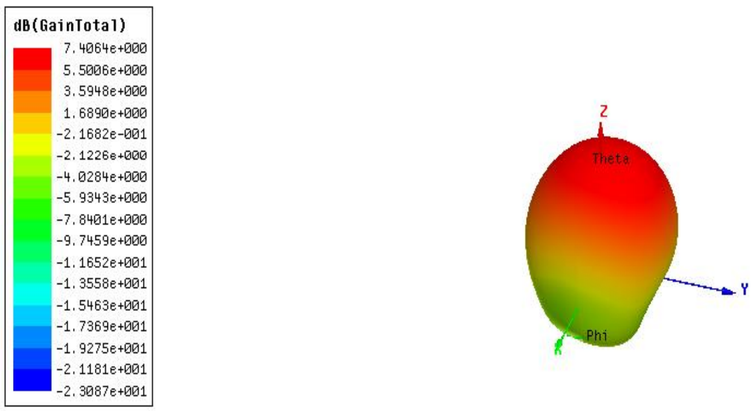


Fig.26 Gain of Model 2

6.1.6 Results

Table 3. Results in tabular form

Gain	7.406 dB
Freq	2.45 GHZ
Directivity	5.6536
Peak gain	5.5309
Peak realized gain	1.0455
Front to back ratio	258.06
Radiation efficiency	0.97831
Lower band freq/ Higher band freq	2.30/3.98

Table 4. The frequency range at different Voltages corresponding to their capacitance value

Voltage	Capacitance	Value of lower band [GHz]	Value of higher band [GHz]	Freq ratio f2/f1
2 V	0.74 pF	2.1060	3.0508	1.452
5 V	0.56 pF	2.2261	3.4724	1.559
10 V	0.44 pF	2.2462	3.7739	1.68
20 V	0.35 pF	2.263	4.0352	1.783
30 V	0.31 pF	2.10	4.055	1.928

Chapter 7
RESULTS AND DISCUSSIONS

7.1 Introduction to Proposed Work

As there is a fast increase in the expansion of communication, reconfigurable antennas yield the most consideration. Reconfigurable antennas are 'smart' enough to adjust their operating characteristics such as frequency, polarisation and radiation pattern [11]. This type of antennas is usually adopted because of its reasonable and low cost; apparent to make and very favourable for the future wireless communication [2]. Its exceptional features like capability to reconfigure, minimization in size as it uses single wireless platform by integrating multiple wireless standards, low cost have provided the reconfigurable antennas leverage to be used for wireless communication system. Reconfigurable antennas have now been broadly studied over last two decades. The Reconfigurable Antennas uses switching elements to configure the electrical properties of the antenna with its radiation characteristics. This type of antenna makes use of switches, p-i-n diodes, varactor so as to achieve the required tenability in the functionality of antenna [11] [5]. In this paper frequency is being reconfigured with the help of varactor. The fractal term basically means irregular or disintegrated fragments so as to characterize a family of composite shapes which acquire innate self-symmetry and self-affinity in the geometric shapes [26]. Fractal is one such class that present miniaturization in the size of antenna with multiband characteristics [27]. These fractals have a number of attractive characteristics with Euclidean geometries. Fractals are known for having non-integer values for their dimension. Usually geometry dimension can be defined in a number of ways, but generally simply used definition is the dimension for self-similarity. So as to achieve this value, the geometry is basically separated into scaled down, but alike copies of itself. If there are *n* copies of the novel geometry and is then scaled down by the fraction *f*, then the similarity dimension *D* is basically defined by Eq.22 [28]. The fractal used in this paper is sierpinski gasket that is triangular in shape. Examples of fractal applications include cell phones and many more wireless mobile devices like laptops. Recently Reconfigurable antennas have shown a lot of research interest for applications like cognitive radio, radar system, satellite communication system and also supported a large number of standards such as WiMAX, Wi-Fi, LTE (Long term Evolution).The aim of this research is to implement the reconfigurable antenna loaded with the varactor using the fractals so as to reduce the antenna's size and get the multiband so that solo antenna can be used for many applications.

$$\boldsymbol{D} = \frac{\log \boldsymbol{n}}{\log(\boldsymbol{1}/\boldsymbol{f})} \tag{22}$$

7.2 Antenna Configuration and Design

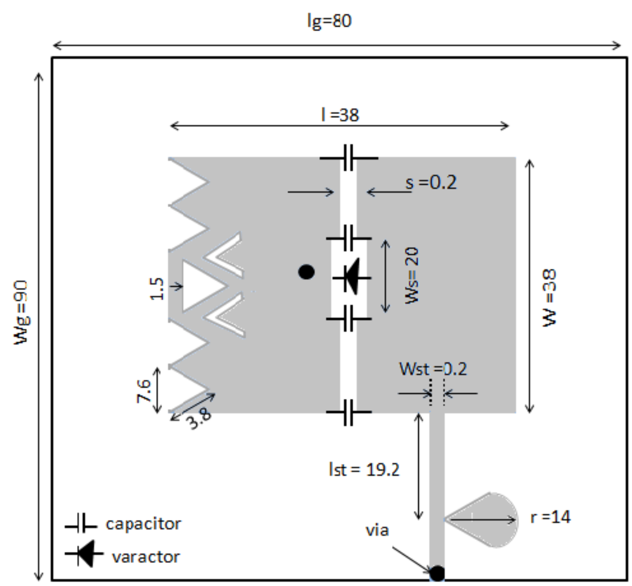


Fig.27 Antenna geometry of reconfigurable multiband patch antenna with an integrated DC biasing network using fractals.

Fig.27 shows the projected design of reconfigurable antenna in which it is loaded with the varctor plus the dc biasing circuit. The antenna is probe-fed patch antenna that means feed can be given anywhere on the patch.The dimensions of the antenna is illustrate in Table 5. The software being used to design the proposed antenna is HFSS.The substrate being used is Rogers RT/duroid 5880 having dielectric constant ε_r=2.2, thickness (h)=3.175mm and loss tangent δ=0.0009 [7].

The antenna operates at frequency 2.45GHz that is basically used for antenna.The slot is loaded with the varactor so as to provide electronic tuning with the help of dc biasing circuit that is provided at the right side of the patch. The Varactor of high quality is used i.e. SMV 1430 manufactured by Skyworks. With the help of this frequency is being tuned by varying the different voltages from $2V \leq V \leq 30V$ and hence corresponding capacitors varies from $0.74pF \leq C \leq 0.31pF$.The corresponding capacitor value of voltages for SMV 1430 is shown in Table 6. To set up the circuit that is biased, the patch is being prorated into 2 halves by a slit that is narrower of width(s=0.2) so as to evade the short circuit in the terminals of varactor. In addition to this,four capacitors of 68nF are installed on the slit to preserve RF continuity. The DC signal have the ability to be passed through the probe feed alongwith the bias tee having width(W_{st}=0.2) that superimposes DC signal and RF signal. In order to complete the circuit, the right part of the patch is grounded with the help of a metallic via[3]. The left side of the patch is loaded with the fractals so as to minimize the size of antenna and to attain multiband. Many iterations have been carried out before getting the actual results. Any type of iterations can be carried out so as to fit on the patch. In this paper, the fractals is formed by first patch width is divided among five isosceles triangle having two sides same having dimension 3.8mm and third side having dimension 7.6mm. Then the centre triangle is moved 1.5mm downwards and two another traingles of same dimension are superimposed over each other 1mm apart and then these triangles are subtracted from the patch thereby resulting in the fractals(all traingles are of same shape and size) as shown in Fig.28

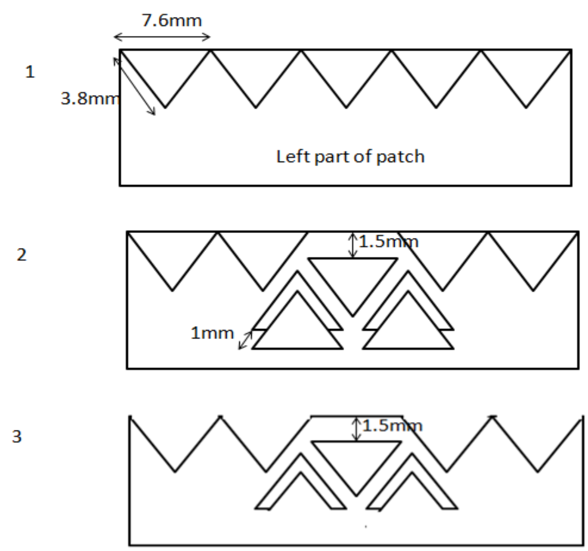


Fig. 28 Steps to cut fractals on the patch.

Table 5 Dimensions of Main elements of the antenna

Main Elements of Antenna	Dimensions(mm)
Ground Length (lg)	80
Ground Width (Wg)	90
Patch Length(l)	38
Patch Width(w)	38
Slot length	0.5
Slot width	20

Table 6 Capacitor Values corresponding to different voltages

Voltage(in Volts)	Capacitor Value (in pF)
2	0.74
5	0.56
10	0.44
20	0.35
30	0.31

7.3 RESULTS:

The analyzed results of the design proposed are illustrated in this particular chapter with their brief discussion.

7.3.1 Reflection Coefficient

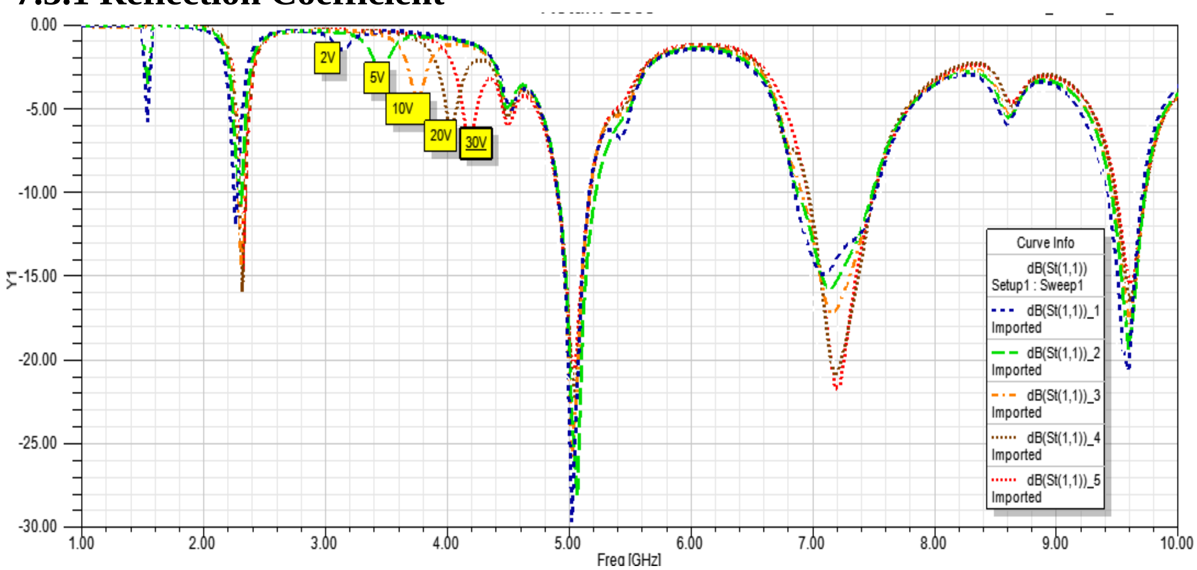


Fig.29 Reflection coefficient of the proposed antenna versus the frequency corresponding to different biasing voltages.

The antenna reflection coefficient of the proposed reconfigurable multiband antenna at diffrent DC voltages is illustrated in Fig.29. As mentioned, by varying the voltage from 2V to 30V which corresponds to varying the capacitor value from 0.74pF to 0.31 pF, four resonant frequencies are obtained for all the voltages which are nearly constant i.e f1,f2,f3,f4.The antenna resonates nearly at same frequency for the diffrent voltages i.e. f1 ranges from 2.26GHz to 2.31, f2 is constant resonating at 5.02 GHz, f3 ranges from 7.06 GHz to 7.15 GHz and f4 ranges from 9.54

GHz to 9.59 GHz. The corresponding reflection coefficient for all the resonating frequencies corresponding to different voltages is shown in Table 7

Table 7 Reflection Coeffiecient at different frequencies for different voltages.

Voltage(in Volts)	Reflection Coefficient S11 (in dB)
2	f1= -11.76 f2= -25.68 f3= -14.83 f4= -20.24
5	f1= -13.37 f2= -46.51 f3= -16.19 f4= -23.20
10	f1= -14.05 f2= -23.02 f3= -19.26 f4= -17.56
20	f1= -12.45 f2= -29.36 f3= -25.44 f4= -16.62
30	f1= -12.13 f2= -21.67 f3= -29.74 f4= -17.45

From the Table 7 it is clear that S11≤ -10dB that means antenna is well matched.

7.3.2 Gain

The simulated gain being acheived by the proposed antenna at 2.45 GHz is 7.6 dB. The gain at the differnt voltages has also been calculated and it is observed that when the value of voltage increases cause decrease in the value of capacitance, gain along with effectiveness increases i.e. gain has the direct relationship with the voltage as shown in Table 8. As in this paper voltage range varies from 2V≤V≤30V, gain also changes according to different voltages. The increase in the gain along with the efficiency with the increase in voltage is because of the reason that the value of varactor loss is decreased as the biasing voltage is increased, that match with the relation of proportionate between loss of varactor and the value of capacitor[29]. The attained gain value considers to be a good candidate for applications of wireless communication.

Table 8. Gain Values at different voltages.

Voltage(in Volts)	Capacitance(pF)	Gain(in dB)
2	0.74	7.13
5	0.56	7.45
10	0.44	7.55
20	0.35	7.61
30	0.31	7.63

From the above shown table it is clear that as the voltage increases;capacitance value decreases;gain increases. Hence it is evident to say that with the increase in the voltage,gain is also increased.

7.3.3 VSWR

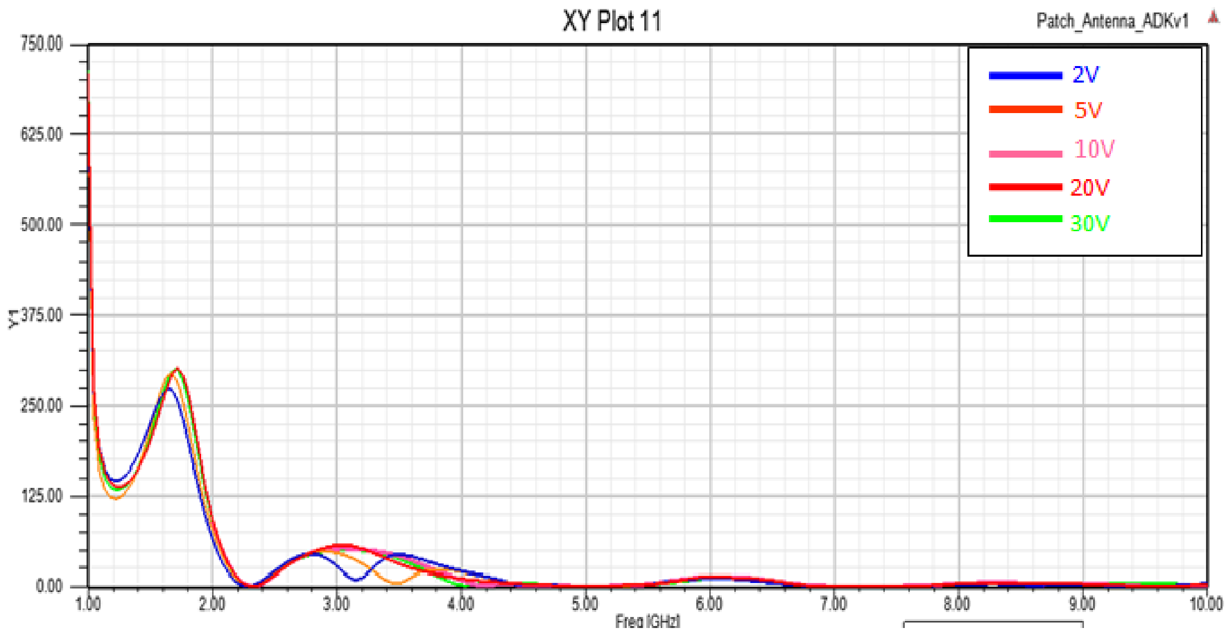


Fig.30 The VSWR of the proposed antenna at different Volatges

The simulated VSWR(Voltage Standing Wave Ratio) of the presented antenna design for multiband at different voltages is shown in Fig.30. The VSWR is basically a function of the return loss that depicts the power that is being reflected from the surface of the antenna. VSWR value ranges from 1 to infinity but the accepted value for the VSWR falls in between one and two. The VSWR values for each resonating frequencies at different voltages is being shown in Table 9.

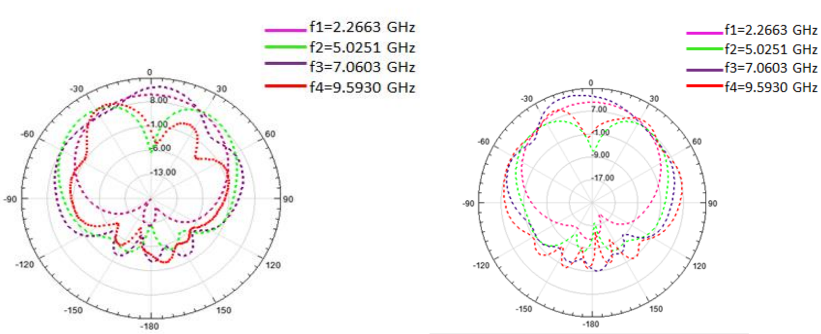
Table 9 Simulated VSWR at different voltages for f1,f2,f3,f4

Voltage(in Volts)	VSWR
2	f1=1.70 f2=1.12 f3=1.41 f4=1.16
5	f1=1.54 f2=1.00

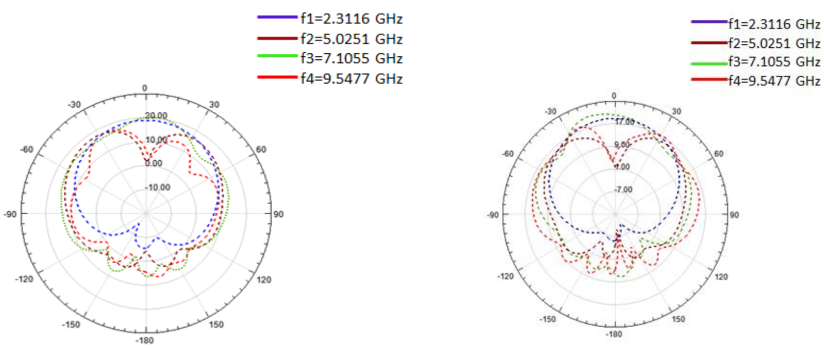
	f3=1.36 f4=1.14
10	f1=1.56 f2=1.07 f3=1.24 f4=1.31
20	f1=1.55 f2=1.15 f3=1.14 f4=1.34
30	f1=1.65 f2=1.18 f3=1.06 f4=1.34

The above table depicts that at different voltages ranging from 2V≤V≤30V, VSWR lies between 1 and 2,therefore, the proposed antenna is sais to be well matched.

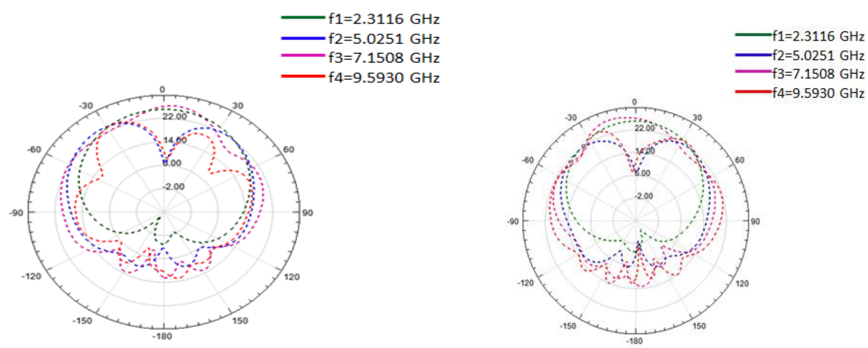
7.3.4 Radiation Pattern



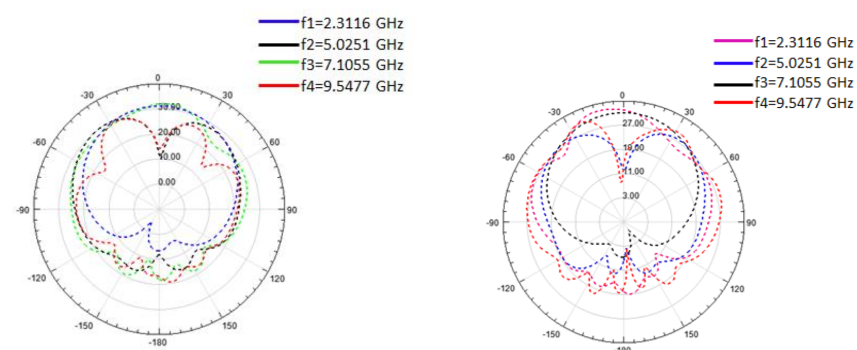
a.


f1=2.3116 GHz
f2=5.0251 GHz
f3=7.1055 GHz
f4=9.5477 GHz
f1=2.3116 GHz
f2=5.0251 GHz
f3=7.1055 GHz
f4=9.5477 GHz

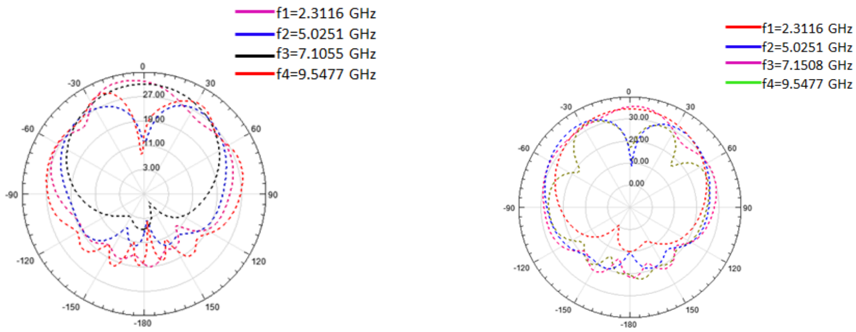
b.


f1=2.3116 GHz
f2=5.0251 GHz
f3=7.1508 GHz
f4=9.5930 GHz
f1=2.3116 GHz
f2=5.0251 GHz
f3=7.1508 GHz
f4=9.5930 GHz

c.


f1=2.3116 GHz
f2=5.0251 GHz
f3=7.1055 GHz
f4=9.5477 GHz
f1=2.3116 GHz
f2=5.0251 GHz
f3=7.1055 GHz
f4=9.5477 GHz

d.



e.

Fig.31 Radiation Pattern for E-Plane(left) and H-plane(right) at different voltages corresponding to the resonating frequencies (a)2V (b)5V (c)10V (d)20V (e)30V.

The antenna radiation pattern at all the frequency bands corresponding to E-plane (xz) and H-plane (yz) is shown in Fig.5. The figure depicts the principal planes at different applied biased voltages i.e. E-plane has the values (phi=0 degrees and theta=all values) and H-plane has the values (phi=90 degrees and theta=all values).

Chapter 8

CONCLUSION AND FUTURE SCOPE

8.1 Conclusion

Reconfigurable Antennas has numerous applications in the areas of communication. They inherent the capability so as to change the characteristics of the circuit and also the radiation pattern in the real time. The operation of different types of functionalities on the single antenna requires some reconfigurability so as to attain the radiation pattern along with the frequency suppleness. According to the requirement of the user the parameters of antenna are changed. The fractal technology has numerous advantages as it provides reduction in the antenna's size, provides enhanced impedance matching and the main advantage of using fractals is that it provides multiband applications. So in this thesis, the design is based on the combination of two i.e. a reconfigurable antenna loaded with the varactor diodes for fast frequency tuning and biasing circuit incorporated with the fractals so as enable the users to use single antenna for different applications by the switching ability of reconfigurable antenna along with the advantages of fractals as providing the reduction in size of antenna along with the multiband applications. The proposed technique depicts the practicability of varactor diodes (SMV 1430) at different voltages that is being operated electronically and multiband operation lies on the concept of fractals. The presented design results in four resonating frequencies that can be used for different applications depicting its multiband feature having a gain of 7.63dB which is a superior contender for being used in applications of communication. The applications of the proposed antenna for various bands are Wi-Fi, WiMAX, LTE, Satellite communications. Ansoft HFSS software was being used to implement the design and also for analyzing the results.

8.2 Future Scope of the Research

The proposed work can be utilized in different direction in the future as:

a. There are many different types of fractals having the different geometries can be used.
b. The each iteration that is being carried out in fractal corresponds to definite range of frequencies, so it can be further used in broadband antennas.
c. The concept of reconfigurable antenna and fractal can be used in 5G technology by enhancing the frequency agility of the antenna.

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