DESIGN OF FREQUENCY RECONFIGURABLE MICROSTRIP ANTENNA FOR 5G APPLICATIONS

A PROJECT REPORT

Submitted by

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ABSTRACT

A compact frequency reconfigurable U slot antenna for 5G applications is presented. The proposed antenna consists of double slot with three RF PIN diodes placed at different position on the patch to achieve frequency reconfigurability. Based on the switching state of the PIN diodes, the antenna is capable of working at eight different frequency ranges. The radiation pattern of the antenna is nearly omni directional for all the frequency bands. The simulated return loss for all the frequency bands meets the permissible limits.

The overall dimension of the antenna is 24 x 20mm^2 for the ground plane. Without changing the size of the antenna, it can operate in single band and double band by changing the state of the RF PIN diodes. The antenna parameters such as VSWR, return loss and radiation pattern are simulated. The analysis is performed using Ansoft HFSS v19.2 software.

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CHAPTER 1

INTRODUCTION

The word antenna is derived from Latin word which is called a transmitting/receiving device. Antennas are the key components in wireless communication system. An antenna is a type of transducer which converts electrical signal to electromagnetic signals. Patch antennas are extremely useful in many applications like satellite communications and various military applications such as GPS, mobile phone, missile systems, etc., due to light weight, simple structure and easy implementation. The main advantages of patch antennas are as follows:

- Low cost to fabricate.
- Manufacturing is easy.
- Radiation efficiency.
- Support both circular and linear polarization.
- Light weight.
- Easily integrated with the microwave circuits.

The increasing demand for modern mobile, satellite and wireless communication systems have driven many researchers to work on improving performance and enhancing applications of patch antennas.

The reconfigurable antenna has become a distinct area in the modern wireless applications because it empowers a single antenna to be used at various systems. Reconfiguration means, achieve modification in antenna's operating frequency, polarization or radiation characteristics dynamically. The characteristic modification of an antenna can be obtained by redistribution of current in the surface of the antenna. There are many techniques involved in which the antenna current can be redistributed, either by altering the geometry of an antenna or by changing the electrical properties of an antenna. This can be achieved by RF switches, varactors, or tuneable materials. These concepts of reconfigurability significantly decrease the complexity of hardware by reducing the number of components.

There are different techniques to achieve reconfigurable aspect of the antenna structure; for example,

- By varying the physical structure of an antenna
- shifting the feeding point
- Implementing the antenna arrays, etc.

It is essential to note that while changing one parameter in the antenna characteristics then it can affect the other parameters. Therefore, during the design of an antenna all the antenna characteristics should be analysed simultaneously in order to achieve the required configurability.

Different types of parameters of the antenna are:

- Radiation pattern
- Beam width
- Radiation intensity
- Directivity
- Efficiency
- Gain
- Polarisation
- Bandwidth

1.1 RADIATION PATTERN:

An antenna radiation pattern or antenna pattern is defined as a mathematical or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In pattern of reconfiguration, the antenna beam will be shifted from one direction to another. Thus, by using pattern reconfiguration the antenna signal in desired direction can be reinforced. For this category, the radiation pattern is changed in terms of shape, direction or gain. It reduces the effects of noisy environments by changing the null positions, and it saves energy by adjusting the main beam signal towards the intended user to improve the overall system performance. When compared to the traditional broadband antennas, frequency reconfigurable antennas have a relatively smaller size and higher isolation.

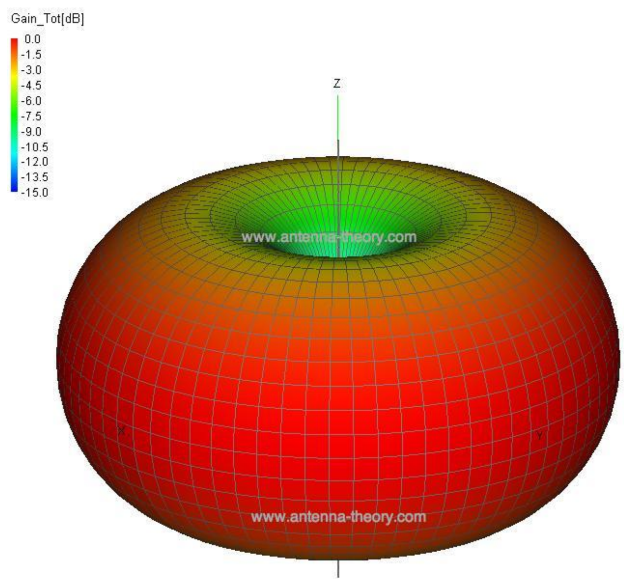

Fig 1.1 3D Radiation Patter

Radiation pattern can be defined for the far-field. It is a function of directional coordinates. There can be field patterns or power patterns .

The power pattern is usually plotted on a logarithmic scale or more commonly plotted in decibels (dB).

1.2 BEAM WIDTH:

- The beam width of an antenna is a very important figure of merit and often is used as a trade-off between the width and the side lobe level; that is, as the beam width decreases, the side lobe increases and vice versa.
- The beam width of the antenna is also used to describe the intended capabilities of the antenna to distinguish between two adjacent radiating sources or radar targets.

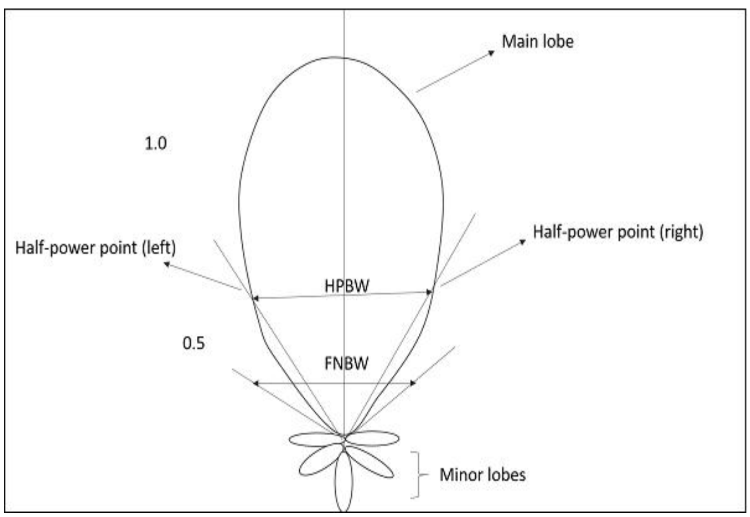

Fig 1.2. Beam Width

1.3 RADIATION INTENSITY:

One steradian is defined as the solid angle with which the vertex is at the center of a sphere of radius ‘r’ that is subtended by a spherical surface area

Which is equal to that of a square with each side of length ‘r’?

1.4 DIRECTIVITY:

It is defined as ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

- The average radiation intensity is equal to total power radiated by the antenna divided by 4π.
- It also stated more simply, that the directivity of a non-isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source.

$$D_{max} = D(\theta,\varphi) = U(\theta,\varphi) / U0 = 4\pi U(\theta,\varphi) / P_{rad} .$$

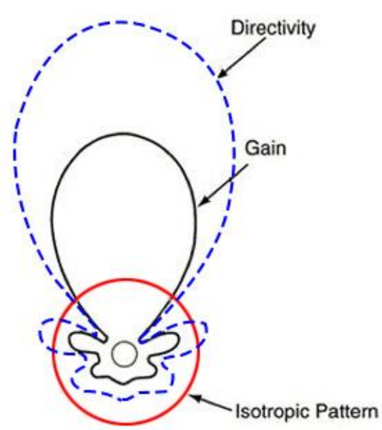

Fig 1.3 Directivity

1.5 EFFICIENCY:

- The total antenna efficiency e_0 is used to take into account considering the losses at the input terminals and within the structure of the antenna.

- e_0 is due to the combination of number of efficiencies

$$\boxed{e_0 = e_r e_c e_d}.$$

$$\begin{aligned}
e_o &= \text{total efficiency},\\
e_r &= \text{reflection(mismatch) eff.},\\
&= (1 - |\Gamma|^2),\\
e_c &= \text{conduction efficiency},\\
e_d &= \text{dielectric efficiency},\\
\Gamma &= \frac{Z_{\text{in}} - Z_0}{Z_{\text{in}} + Z_0},\\
\text{VSWR} &= \frac{1 + |\Gamma|}{1 - |\Gamma|}.
\end{aligned}$$

Γ = voltage reflection coefficient at the input terminals of the antenna, Zin = input impedance of an antenna, Z_0 = characteristic impedance of the transmission line. VSWR = voltage standing wave ratio

1.6 GAIN:

- The gain of an antenna can relate to the directivity.
- In addition to the directional capabilities it accounts for the efficiency of the antenna.
- Gain does not account for losses arising from impedance mismatching (reflection losses) and polarization mismatching (losses).

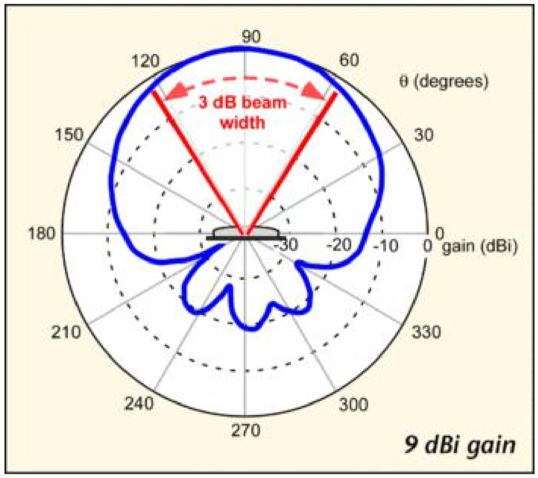

Fig 1.4 2D Gain

1.7 POLARISATION:

Polarization is a curve traced by the end point of the arrow or the vector representing the instantaneous electric field. The field should be observed along the direction of propagation.

- Polarization is classified in different ways such as linear, circular, or elliptical.
- If a vector describes the electric field at a point in space as a function of time which is always directed along a line, then the field is said to be linearly polarized.
- In general, the figure that the electric field traces are an ellipse and the field is said to be elliptically polarized.

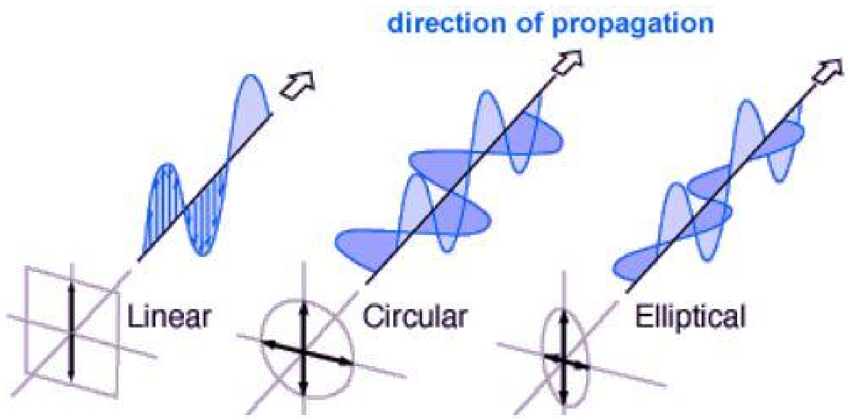

Fig 1.5 Types of polarization

1.8 Bandwidth:

The term bandwidth defines the range of frequencies, with which an antenna can achieve, in order to obtain a desirable behavior of a certain characteristic. The bandwidth can be considered as the range of frequencies, on either side of a center frequency (usually the resonating frequency for a dipole antenna), where the antenna characteristics such as (input impedance, radiation pattern, beam width, polarization, side lobe level, gain, radiation efficiency, beam direction) are within an acceptable value of those at the center frequency (at -10 dB). However, as a range, two boundaries define the lower and upper frequency limits, and the ratio of its size to the center frequency as a percentage define the percent bandwidth for a narrowband antenna, thus occupying a small space quantity on the RF spectrum–given by equation (2.11); otherwise, for a Broad band (or wideband) antenna the bandwidth is defined as the ratio of the upper to lower frequencies as written in equation

$$B_f = \frac{(f_H - f_L) \times 100}{f_c}$$

$$B_r = \frac{f_H}{f_L}$$

Where:

B_f _Fractional bandwidth in Hz percentage.

B_r _ Bandwidth ratio.

f_H_ Upper frequency in Hz.

f_L _Lower frequency in Hz.

1.9 FEEDING TECHNIQUES:

The feeding techniques plays very important role in case of efficient operation of antenna to improve the antenna input impedance matching.

The various types of feeding techniques are:

- Micro-strip line feed
- Capacity feeding
- Coaxial feeding

1.9.1 Micro-strip feeding:

A conducting strip is connected to edge of the patch. The feed can be given to the substrate.

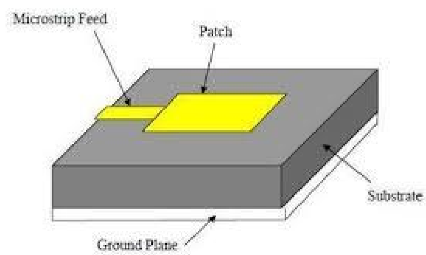

Fig 1.6 Micro Strip Feeding

1.9.2 Capacitive feeding:

Feeding can be done to the small patch instead doing main radiating patch.

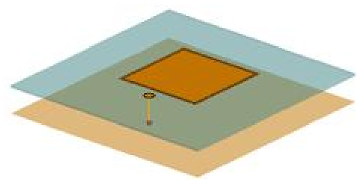

Fig 1.7 Capacitive Feeding

1.9.3 Co-axial feeding:

This is a very common feeding technique for the micro strip antenna and also called as the probe feeding technique.

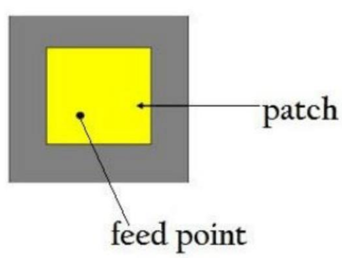

Fig 1.8 Co-axial feeding

1.10 MICRO-STRIP ANTENNA:

The demand for smaller antenna size in order to meet miniaturization in mobile devices has increased the need for micro strip antennas since its invention in because of its extremely thin profile, light weight, mass production by print circuit technology and easily integrated with IC's .It has have found main applications in military aircraft, missiles, rockets, and satellites. Due to high cost of substrate and fabrication cost and also communication system was not able to adopt this kind of antenna it was not popular in commercial sector. But during last decade the development and manufacturing cost of the micro strip antenna has dropped significantly, due to reduction in the cost of substrate material and manufacturing process, also the newly developed CAD tools for simulation and analysis. Much significant progress has been reported in the design of compact micro strip antennas with broadband, dual-frequency, dual polarized, circular polarized. Configurability in this type of antenna has attracted much attention of the researches as switches can be easily implemented and fabricated without much difference in measurement between fabricated and simulated antennas. There are some disadvantages of micro strip antenna like High quality factor, Narrow bandwidth; Spurious feed radiation and Low efficiency.

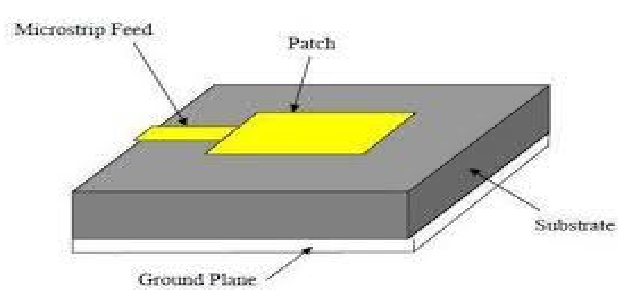

Fig 1.9 Structure of the Micro strip Antenna

Micro strip antenna provides much needed demand of low profile, light weight and also can be easily integrated with ICs and switching elements. It can be produced in large amount by printed circuit technology and thus integrated in mobile phones and other wireless applications like satellite communications, spacecraft, radars, wireless phones and wireless computer networks for large scale production. The major applications of micro strip antennas are:

- **Mobile Communication:** - Antennas used in mobile applications should be of light weight, low profile and energy efficient. Due to large number research going on this field, its disadvantages like low bandwidth are minimized. It can be integrated in hand held gadgets or pocket size equipment, cellular phones, UHF pagers

- **Satellite Communication:** - micro strip antenna used in satellite communication should be able provide circular polarization. This antenna can be reconfigured easily by dual feed network and other techniques.

- **Global Positioning System**: - for this application an Omni directional micro strip antenna with wide beam and low gain can be easily design with dual frequency operation in L band which is used for GPS.

- **Direct Broadcast Satellite System**: - for the television services a high gain of (~33dB) antenna should be used. An array of micro strip antenna with circular polarization can be used.

- **In Radar Applications:** - An array of micro strip antenna with desired gain and desired beam width can be used for Radar application such as Marine radar, Man pack radar etc.

CHAPTER 2

LITERATURE SURVEY

The patch antenna first idea was appeared to be proposed by Deschamps & sichak in 1953.

The first patch antenna idea appeared to be originated in early 1950's, but there hasn't been much activity for nearly 2 decades. For the most part because of its inherent narrow bandwidth. After some time, it started to draw the attention in 1970's. As the antenna designers started to cherish the edged offered by this type of antennas. Which include low profile, conformability of a shaped surface ease of fabrication and compatibility with integrated circuit technologies.

In the last 3 decades, extensive studies have been devoted to improving the bandwidth and other performance characteristics.

Frequency agile Micro strip Patch to Slot Antenna was designed by H. A. Majid, M.K.A Rahim

The frequency agile patch to slot antenna has been proposed. This proposed antenna consists of the micro strip patch and slot in the ground plane seven switches using RF PIN diode BAR 52-02V positions at the slot to produce seven reconfigurable frequencies at 1.87GHz,1.96GHz,2.08GHz,2. GHz,2.41GHz,2.74GHz and 3.19GHz.

This patch resonates at the highest resonant frequency whereas the slot resonates at the lower resonant frequencies. It was found that at the highest frequency the radiation pattern while at the lower frequencies, a near omni-directional radiation patterns are obtained.

Flexible Millimetre -Wave Frequency Reconfigurable Antenna for Wearable Applications in 5G Networks was proposed by syeda fizzah jilani, Berit grenike, Yang hao in the year 2016

To keep up the pace with the ongoing research and development on the millimetre wave antennas for 5G generation networks, in this it integrates the frequency reconfigurability in a flexible antenna operating at millimetre wave frequency spectrum reconfigurable antenna is designed on (LCP) liquid crystal polymer .Substrate which is well recognised for its distinguishing performance at higher frequencies. Antenna geometry consists of radiating patch shape of the radiating patch is tuning fork and it consists of two subs. These two subs can be made part of radiating elements of two switches MMW antenna offers a frequency reconfiguration over a frequency range 20.7-36GHz by four different switch configurations pin diodes have been assembled of LCP substrate as a switch.

Frequency Reconfigurable Micro strip Patch Slot Antenna with directional radiation pattern was proposed by M.R. Hamid, F.M. Ismail in the year 2014

They have developed frequency reconfigurable slot patch antenna with reflector at the back of an antenna which consists of micro strip patch antenna and a micro strip slot antenna where the slot antenna is positioned at the ground plane underneath the patch, with the three switches placed in the slot. Then the antenna is capable to reconfigure up to 6 different frequency bands from 1.75GHz-3.5GHz.The antenna produces three different frequency bands with directional pattern while the micro strip slot antenna produces three different frequency bands with directional radiation pattern while the micro strip slot antenna produces and other three frequency bands with directional radiation pattern. Due to reflector placed at the back of the antenna, the radiation pattern is directional at all frequency bands

Frequency reconfigurable antenna for ku-band applications was proposed by T.V. Rama krishna, BTP Madhav.

In this paper a unique design of frequency reconfigurable antenna is approached by using KU Band downlink for especially in satellites. A rectangular slot with 4 pin diodes, where the frequency reconfigurability is obtained. The diodes are used in the defected ground structure where they help in achieving reconfigurability very easily. They have designed the antenna and fabricated it on FR-4 substrate of di electric constant 4.4 and thickness 1.4mm antenna is working at different frequency and polarisation are usually installed for better reception quality at different position in wireless platform.

UWB Frequency Reconfigurable patch antenna for cognitive radio applications was proposed by G. Aishwarya, M. Anand Reddy, J. Aarthi in the year 2017

In this paper 2 ultra-wide band frequency Reconfigurable micro-strip patch antenna for cognitive radio applications were designed in which consists of rectangular path with micro strip feed-line and a partial ground plane. Slots were well placed in patch and ground plane to enhance the bandwidth. The radiating element of dimension 10.5mm into 14nm(l*W) was placed on FR-4 epoxy dielectric substrate with relative permittivity of 4.4. The antenna has some patch structure but different ground plane structures. Each of the antennas can operate in UWB (3.1GHz to 10.6GHz) range and their corresponding sub bands switching from UWB to sub bands is enable pin diodes placed in the horizontal slots in the ground plane

A New Differentially-Fed Frequency Reconfigurable Antenna for WLAN and sub 6GHz 5G Applications was proposed by Gui Ping Jin, Chu Hong Deng in the year 2017

The differential fed frequency antenna consists of two substrates which are separated by an air gap with 2.5mm thickness,4 pin diode switches are arranged on two substrates, the excitation of radiating patch and the length of feed lines can be controlled, then two different operating frequencies can be obtained. This differentially fed frequency can be switched between two states operating at 2.4 and 3.5GHz band. The antenna is good for 2.4GHz and sub 6GHz (3.5)5G applications. The employment of the pin switch makes the antenna which can operate in dual frequency bands (2.45&3.5GHz). Because of this simple structure makes the differentially fed frequency reconfigurable antenna easy to fabricate

Millimetre wave's frequency reconfigurable antenna for 5g networks was proposed by Farooq Azam and Shahid Bashir in 2015. To offer faster speeds and reliable connections on smart phones and another device the antenna is designed. This antenna can be expected to operate on 28 and 38 GHz bands. Single antenna which can switch to operate on multiple bands. The antenna was designed on a roger R5880 substrate having dielectric constant 2.2 and loss tangent 0.0009. It consists of two slots in the ground and a simple radiator on patch. Reconfigurable frequency can be obtained by placing 3 pin diodes in the slots that are placed on the ground. The operation of the frequencies can be controlled by a switching the states of the pin diodes. The antenna can cover a wide range of frequency from 25.6 to 39.3 GHz by simply switching the diodes by turning it on and off so that it can cover 28 and 38 GHz bands that are anticipated to be working for 5g communication. The size of the antenna is 10×7mm^2 which has a good gain of 6.5 to 8.4 dB as well as 85%efficiency in the two bands

B. Siva prasad and p.mallikarjuna together proposed the co-planar wave guide fed fork shaped antenna designed with reconfigurability for switching between the bands of LTE, Wi-Fi and W-LAN .A navel closed hut shaped ground plane is used for the construction of antennal mode for good impedance matching with feed line . The basic structure of antenna model is working in UWB range from 3.1 to 10.6 GHz. The adjacent strips of the monopole consist of the slots for the placement of pin diodes. The switching operation of diodes provides frequency reconfigurable nature in antenna between LTE (2.1 - 2.2 GHz), Wi-Fi (2.4-2.7 GHz) and W-LAN (5.6 - 5.8GHz). This antenna gives the realization gain of 4.5db and efficiency more than 70% in the operating bands

Frequency Reconfigurable UWB antenna for wireless applications was proposed by Rithesh kumar and Mithilesh in the year the year 2019.
This antenna contains two bands that can achieve UWB (3.1 - 10.6 GHz) this can be achieved by two dual bands and two narrow bands switching states by implementation of pin diodes. the antenna covers wireless standards such as W-LAN, Wi MAX, Wi-Fi and UWB with return loss s11< -10 dB and the frequency Reconfigurable UWB antenna can also operate 9.2 GHz to include the airborne radar applications. The UWB monopole antenna can be reconfigured to other frequency bands by using an inverted L and rectangle shaped slotted structure placed on the ground plane.

Reconfigurable antenna for 4G, LTE and 5G applications was proposed by Gohar Awan and Tariq Mohammad.
In this paper they focused around miniaturization and reconfigurability of antennas. The antenna deals with five or more bands of LTE (2140MHz,

4200MHz, 5650MHz, 5900MHz and 12.04GHz). The antenna provides wide range of applications for modem communication systems. The antenna is Efficient and no mobility issues in it as where in the previous antennas. It is an important feature of RF system with single device which can access more than one wireless standards. The reconfigurability can be obtained by changing frequency, polarization, radiation pattern and their combination and the diodes are used for reconfigurability.

Compact frequency reconfigurable slot antenna for wireless applications was developed by Liping Han, Caixia Wang, Xinwei Chen, Wenmei Zhang.

A compact frequency Reconfigurable antenna was designed for LTE(2.3GHz), AMT-fixed service(4.5GHz) and W-LAN(5.8GHz) applications. In this antenna a u-shaped slot with short ends and an L shaped slot with open ends are etched in the ground plane to realise dual band operation. By inserting two pin diodes inside the slots, easy reconfigurability of 3 frequency bands over the frequency ratio of 2.6:1. To reduce the cross polarization of antenna another L shaped slot is introduced symmetrically. Compared with conventional reconfigurable slot antenna, the size of the antenna is reduced by 32.5%.

A simple frequency reconfigurable antenna which functions at UMTS/IMT 2000 and ISM Band using the principle of controlling the antenna resonant frequency f_r by PIN diodes switches. The selection of different modes in was achieved by using either feed or ground switching. For example, by using feed switching, the antenna can cover global system for mobile communications (GSM) standard, which are GSM850 and GSM900 for lower band and digital cellular service (DCS) for upper band in mode 0. Furthermore, GSM900 was covered for lower band while for upper band, personal communication system (PCS) and universal mobile telecommunications system (UMTS) was covered in mode 1. Reconfigurable multiband slot dipole antenna that can select a separate frequency bands are proposed. It can switch to single, dual, triple and multiple band modes by using hard - wire switches. Switches are located in the slot of the antenna which can control the arms of the dipole either switch in and out from the slot edges. An open-end straight slot line and the PIN diodes to achieve frequency re configurable capability is proposed in. The PIN diodes along with DC bias network are located at specific regions to create short circuit or open circuit across the slot. By carefully controlling these diodes, the antenna will be operated as the conventional λ/4 slot antenna. The design of a combined frequency- and polarization re configurable antenna is presented in. Shorting posts around the patch are used to enable the antenna to radiate three polarization's, and varactor diodes are employed to achieve independent frequency tuning for each polarization state. A compact Planar Inverted Antenna (PIFA) suitable for cellular telephone applications is presented in. The quarter-wavelength antenna combines the use of a slot, shorted parasitic patches and capacitive loads to achieve multiband operating frequency. The antenna operates from 880 to 960 MHz and 1710 to 2170 MHz covering GSM, DCS, PCS, and UMTS standards. A compact five-band planar inverted-F antenna (PIFA) for mobile phones using helical feeding and shorting lines, wide folded patch, and two long slots is presented in. The antenna showed wide band characteristics covering DCN (824-894 MHz), GSM (880-960 MHz), DCS (1710-1880 MHz), USPCS (1850-1990MHz), and WCDMA (1920-2170 MHz) within 3.0:1 VSWR. And controlling the two slots showed that the antenna’s low/high resonant frequencies can be independently obtained. HFSS is a commercially available finite element method solver for electromagnetic structures. The software includes a linear circuit simulator with integrated optometric for input and matching network design. HFSS solver incorporates a powerful, automated solution process, so we need only to specify geometry, material properties and the desired output. With those reference, the HFSS will automatically generates an appropriate, accurate and efficient adaptive mesh for solving the problem using the selected solution technology

The antenna is based on a FR4-epoxy substrate with dimension of 50mm X 28mm with the dielectric constant, ε_r of 4.4 and a thickness of 1.6mm. The patch which is rectangular is of 17.56mm X 13.2mm dimension, and is fed using a 3mm-wide micro strip line. The ground plane is constructed in such a way that, a rectangle of dimension 39mm X 18.5mm is subtracted from the full ground plane at the position (5.5,9.5, -1.6). Later, four symmetrical 1.4mm-wide rectangular slots are created onto the ground plane. The slots are at 7mm and 12mm respectively from the antenna's symmetry axis. Four 1.4mm X 2.5mm PIN diodes, PD1, PD2, PD3 and PD4 are mounted across the slots, as indicated in Fig. 1. In the simulation, uses 1.5Ω for the ON state and 0.35pF for the OFF state of the PIN diodes.

CHAPTER 3

PROPOSED FREQUENCY RECONFIGURABLE MICRO STRIP ANTENNA

We know that now a days wireless communication was developed and wanted overcome the needs of people. Our designed projects specially focus on that particular problems and leads to the frequency reconfigurability micro strip antenna was proposed.

With one antenna it can be able to operate different frequencies for different applications. In order to decrease high data rates and number of antennas we should go with the re configurable micro-strip antenna.

In this we can be able to use only one antenna with wide number of applications. So it became extensively used in wireless communication.

A micro strip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors are usually made up of copper or gold can be virtually assumed to be of any shape. However, conventional shapes are normally used to simplify the analysis and performance prediction. The perfect electric conductors like radiating elements and the feed lines are usually photo etched on the dielectric substrate.

The radiating element or substance may be of different shape like square, rectangular, circular, ring, elliptical or any other configuration. Square, rectangular and circular shapes are the most commonly used structures because of ease of analysis and fabrication. Some of the advantages of the micro strip antennas compared to conventional microwave antennas are Patch antennas find a variety of applications starting from military to commercial, because of their ease of design and fabrication.

Patch arrays extensively used in phased array radar applications and in applications requiring high directivity and narrow beam width. One of the important tasks in the printed antenna design is the selection of a suitable substrate material. The major electrical parameters to be considered as the relative dielectric constant and the loss tangent. A higher dielectric constant result in smaller patch antenna but generally reduces bandwidth and results in tighter fabrication tolerances. A high loss tangent reduces the efficiency of the antenna and increases losses while feeding. As a rule of thumb, select a substrate with lowest possible dielectric constant and also lowest cost. Substrate thickness is chosen as large as possible to maximize

Advantages:

- Light weight and low volume
- Fabrication cost is low, hence can be manufactured in large quantities.
- Supports both, linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits (MIC).
- Capable of dual and triple frequency operations

Reconfigurability, when used in the designing and the development of an antenna, it is the capacity to change an individual radiator’s fundamental operating characteristics of an antenna through electrical, mechanical, or other means of operation. Thus, under this condition, the traditional phase of signals between elements in an array to obtain beam forming and beam steering does not make the antenna “reconfigurable” because the antenna’s basic operating characteristics remain unchanged in this case. Ideally, reconfigurable antennas should be able to accept altering the operating frequencies, polarization's, bandwidths, impedance matching and radiating patterns independently to accommodate when there is a change in operating requirements of an antenna. However, the designing and developing these type of antennas poses significant challenges to both antenna and system designers. These challenges will be used to obtain the desired levels of antenna functionality but also to integrate the functionality into complete systems to arrive at efficient and cost-effective solutions. In many cases of technology development, most of the system cost won't come from the antenna but the surrounding technologies which enable the reconfigurability

3.1 NECESSITY OF FREQUENCY RECONFIGURABILITY:

Let us consider the two general applications of reconfigurability, one is single-element scenarios and other one is array scenarios, in single-element scenarios an antenna used in portable wireless devices, such as cellular telephonic device, a personal digital assistant, a laptop or computer or any electronic device. Single antennas typically used in these devices are mono pole or micro strip antenna based and may or may not have multiple-frequency capabilities. Some packages may use two or three antennas for good reception on small devices to increase the probability of receiving a usable signal, but usually only one antenna will used for transmission. The signal transmission from the portable device to the base station or other access point is the weakest part of the bidirectional communication link because of the power, size, and cost restrictions imposed due to portability. Moreover, the portable device is often used in unpredictable and harsh electromagnetic conditions which results in the performance of antenna that are certainly less than optimal condition. Antenna configurability in such a situation could be able to provide numerous advantages. For the instance, the ability to tune the operating frequency of antenna could be utilized to change operating bands, filtering out interfered signals, or to tune the antenna to account for a new environment. If the radiation pattern of antenna is changed, then it could be redirected towards the access point and use lesser power for the transmission of signal, which results in a significant savings in the battery power. The antennas are mostly used in array configuration, feed structures with power dividers/combiners and phase shifter s. For the instance, current planar phased array of the radar technology is typically limited to the both scan angle and frequency bandwidth as a result of the limitations of the individual array elements and the restrictions of the antenna element spacing. These restrictions come from mutual coupling effect on one hand and the appearance on grating lobe on the other hand. Many of these established applications assume that the antenna element pattern is fixed, and all the elements of the antenna are identical, and the elements that lie on a periodic grid. The additional configurability to antenna arrays can provide additional degrees of freedom that may result in wider instantaneous frequency bandwidths, more extensive scan volumes, and radiation patterns that can provide control over the side lobe distributions. There are several antenna structures that are suitable for implementation of re configurable antennas, among them micro strip patch antennas are very attractive structures for various types of re configurable antennas, all such antennas are usually equipped with switches that are controlled by DC bias signals. By toggling the switch between on and off states, the antenna can be reconfigured to obtain better result. The following section describes the design procedure of micro strip patch antenna types presented and different feed types used in this dissertation.

3.2 SOFTWARE DESCRIPTION

3.2.1 Introduction to HFSS

The antennas are designed and simulated using software. Various software available in market are Magus, Cosmol, IE3D, Sonnet, HFSS, FEKO, CST Microwave studio, SEMCAD, efield, XFdtd, EXPIRE, WIPL-ProGEMS. ANSOFT HFSS software is an industry tool to simulate full-wave 3D-electromagnetic fields. This provides good-standard accuracy. The Computer technology has made it a fundamental prerequisite for specialists who are structuring high-recurrence and rapid electronic parts. HFSS manages different state workmanship settling innovations made on the limited component, propelled half and half strategies or coordinated condition for understanding wide scope of utilization. Each HFSS solver hinders an incredible robotized arrangement process, so fashioners need to just determine geometry, properties of materials and the required yield. The 3-D interface permits clients to demonstrate complex 3-D geometry or import CAD geometry.

Fundamentally, the 3-D model is utilized for displaying and to reenact high-recurrence modules known as receiving wires, microwave/RF segments, and biomedical gadgets. Architects remove lattice dispersing parameters (S, Y, Z parameters), and envision 3-D electromagnetic fields (close and far fields).

3.2.2 SOLUTION PROCESS

There are four variations to the solution process

- ❖ Single frequency solution

- Fast frequency solution
- Discrete frequency solution
- Interpolating frequency solution

3.2.2.1 Single Frequency Solution

A single frequency solution makes a versatile or non-versatile arrangement at a solitary recurrence and the initial step for playing out a recurrence clear. A versatile arrangement is one in which a limited component work is made and naturally refined in the regions of most worthy blunder therefore expanding the exactness of succeeding versatile arrangements.

3.2.2.2 Fast Frequency Solution

This kind of arrangement utilizes a current work to produce an answer over a scope of frequencies. The framework displays Adaptive Lanczos Pade Sweep (ALPS) – based solver extrapolating data transfer capacity of arrangement data. This arrangement is utilized for indicate the beginning and consummation frequencies and the interim at which new arrangements are created. A similar work is utilized for every arrangement, paying little respect to the recurrence. While arrangements can be registered and saw at any recurrence, the arrangement at the center recurrence is generally exact.

3.2.2.3 Discrete Frequency Solution

To play out a discrete recurrence clear, the framework utilizes a current work to create an answer over a scope of frequencies. This arrangement is utilized to determine the beginning and closure frequencies and the interim at which new arrangements are produced. A similar work is utilized for every arrangement, paying little respect to the recurrence.

3.2.2.4 Interpolating Frequency Solution

To play out an inserting recurrence clear, the framework utilizes a current work to add arrangements over a scope of frequencies. A similar work is utilized for every arrangement, paying little respect to the recurrence. A uniform mistake resilience exists all through the whole arrangement.

3.3 ANSOFT HFSS EM SIMULATION

The work of electronic devices depends mostly on electromagnetic (EM) behavior. ANSYS HFSS simulation results deliver the accurate answer possible to the less amount of user involvement. HFSS is required to design high frequency and high-speed components in modern electronics devices. Considering the EM environment is critical and predicts accurately how a component-or subsystem or end product accomplishes the field. HFSS address the whole range of EM problems, with losses due to reflection, attenuation, radiation and coupling. The power behind HFSS occurs in the mathematics of the finite element method (FEM) and the integral, proven automatic adaptive meshing technique. As a result, designer focus on design issues rather than spending significant time to determine and create the best mesh. HFSS results good information critical for engineering designs. The results which may contain parameters of scattering (S, Y, Z), imagining the 3D electromagnetic fields, transmission losses, losses due to reflection impedance mismatching, parasitic coupling, and near & fear-field antenna pattern.

3.4 METHODLOGY ADOPTED

In our designed antenna we have introduced one main patch with many parasitic patches. In between parasitic patches we have introduced pin diodes at different places. PIN diodes are the important components in switching the frequencies.

In this work we have chosen FR4 substrate because it is very low in cost and substrate thickness is 0.8 mm. As we mentioned before PIN diodes are the key component in the designing the antenna so this can be able to switch easily.

The rectangular patch antenna is simplest form of patch antenna as shown in and usually designed to operate near the resonance. The length ‘L’ of the patch which is called as a radiator is then selected such that it satisfies the condition of resonance. It is usally chosen close to λ/2 such that the input impedance of the patch is pure real at the desired frequency. Since the two ends of the patch are open, an open-end correction is usually taken into account while calculating the physical length ‘L’ of the patch.

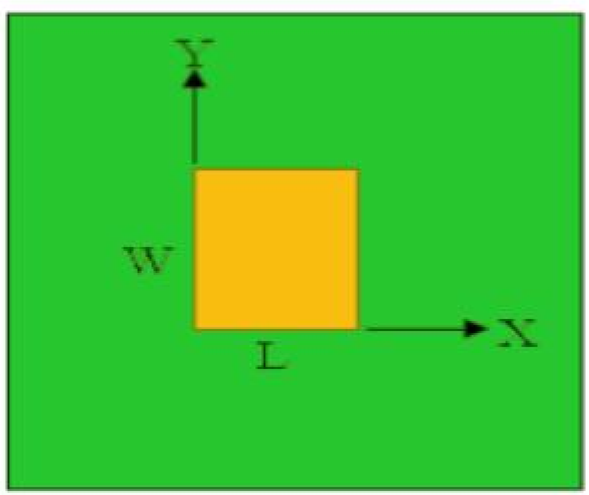

Fig 3.1 Designing of micro strip antenna

The width of the patch ‘W’ generally lies between 0.5 to 2 times ‘L’. The width of the patch can be used to vary the input impedance of the patch. As we have to ultimately match the input impedance of the patch to 50-ohms, we can control input impedance up to some extent by changing the width of the patch ‘W’. If width ‘W’ is chosen very small, the radiating efficiency of an antenna will be reduced. So, there is trade off between the input impedance and radiation efficiency. Once W and L are selected, we can calculate the input impedance of the patch and then we can able to use an impedance transformer to match the input impedance to the 50-ohm along the feed line. The design of a rectangular Micro strip patch antenna begins with (a) choice of a substrate (b) selecting feed mechanism, (c) determining patch width w and (d) selecting the feed location. The micro strip rectangular structure as shown in above has been used to implement a re configurable rectangular patch antenna and triple-polarization diamond shape antenna in this report.

In the following steps rectangular patch antenna design procedure along with required formulation for calculation is given by choosing the required parameters such as frequency of operation (f_r), dielectric constant of the substrate (ε_r), height of dielectric substrate (h).

1) Calculation of Width (W):

For an efficient radiator, a practical width that leads to good radiation efficiencies is given as

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

2) Calculation of Effective dielectric constant (ε_r^{eff}):

The effective dielectric constant due to the air dielectric boundary is given by

$$\varepsilon_r^{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\left(\frac{h}{W}\right)\right]^{-1/2}$$

With the substituting the values ε_r,h and W effective dielectric constant ε_r^{eff} can be calculated using the above formula.

3)calculation of effective length:

$$L_{eff} = \frac{c}{2\sqrt{\varepsilon_r^{eff}}}\left(\frac{1}{f_r}\right)$$

4)calculation of length extension (del l):

$$\Delta L = 0.412h\left[\frac{(\varepsilon_r^{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_r^{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right]$$

5)calculation of the length of the patch:

$$L = L_{eff} - 2\Delta L$$

3.4.1 FEED GEOMETRY TECHNIQUE

The feed geometry morphing method represents the simplest of the three techniques for achieving re configurable antenna operation. In this method, the radiating structured substance called as patch will be remained as constant and only the feed or impedance matching section of the antenna is reconfigured. Like the antenna geometry morphing method, this method is often employed with micro strip geometries because of the relative ease in placing RF switches on planar structures. In the case of micro strip feed lines, there are typically 10 or more sub elements in the transverse direction across the width of the micro strip line for adequate parameter control. They are on the order of in length along the longitudinal direction. Illustrates the implementation of the matching network using the morphing method. In this example a micro strip patch antenna is edge fed by a re configurable micro strip line. The re configurable micro strip line consists of a small array of switchable Micro strip sub-elements. Each of these sub-elements may be said to switch on or off by activating one of the miniature RF switches which will form the interconnections between the sub-elements and compose the overall micro strip structure. The width and length of the feed line is altered to change the impedance of the micro strip. The grey boxes represent inactive sub-elements and the boxes represent active sub-elements. The top left configuration in below figure shows the micro strip patch antenna and the available micro strip feed lattice. The top right sub-element arrangement shows the feed configured as a narrow micro strip line having a characteristic impedance. The patch antenna operates in a radiation mode that is specified by the feeding configuration technique. The bottom two arrangements show the Micro strip feed line configured in two other possible formations. These variations in feed impedance then excite different radiation modes in the Micro strip patch antenna.

The matching network morphing technique carries the distinct advantage of being extremely simple to implement in practice. The only component of the antenna that is changed is the feed network and thus the complexity of the design is minimized. As a result, the number of physical switching components is kept to the minimum level and switch reliability becomes less of an issue. Conversely, this type of methods will exhibit the disadvantage of limited reconfigurability for an antenna. The antenna operation is varied only by making the changes for matching. Consideration will not given to other characteristics of radiation. Because the principal radiation mode could be altered by the impedance mismatch, and the electrical performance characteristics are likely to change as well.

CHAPTER 4

RESULT AND DISCUSSIONS

This chapter presents the design of a novel dual band frequency reconfigurable antenna for 5G applications. The Ansys HFSS software is used in modeling and simulating the designed antenna.

The rectangular shape patch element is backed by an FR4 substrate with a height of 1.6mm and relative permittivity (εr) of 4.4 and a tangent loss of 0.019. Using the metallic ground plane the other side of the patch is embraced. The optimized dimension of radiating patch is 18×13mm^2 and the ground plane is 24× 20mm^2.The FR4 substrate is used in the antenna design due to its prominent features such as feasibility and affordability. The proposed antenna is excited by 50Ω micro strip feed line to attain fabulous impedance matching.

Feeding techniques of antenna is very important criteria to be consider while designing of an antenna. In this design, single fed micro strip line inset feed technique is used due to its features such as simple in figure and easy to fabricate.

U shape slot have been made in the patch. Three PIN diodes are loaded in slots. By controlling three PIN diodes through the corresponding DC voltage source, frequency reconfiguration can be achieved. The effective length of a resonant slot antenna is varied by using RF PIN diode switches to obtain resonant operating frequencies. RF switches are utilized in the design of antenna to earn wide tuning range that can be used for commercial and military applications. The transmission line model is implemented to calculate the basic dimensions of the conventional MSA.

The BAR50-02V PIN diode is used as switching element and is placed in the slots to attain frequency reconfiguration. According to the data sheet of the BAR 50-02Vthe diodes are modeled by a resistance of 3 Ω for ON state and a parallel circuit with a capacitance of .12pf and a resistance of 5KΩ for OFF state. We use Ansoft HFSSv19.2 software to simulate our design

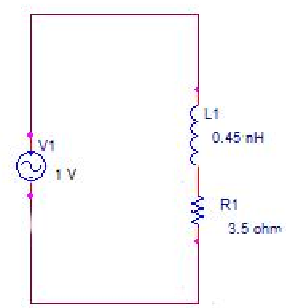

Fig 4.1 Equivalent circuit of PIN diode in forward bias

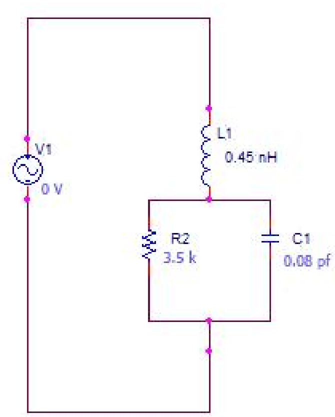

Fig 4.2 Equivalent circuit of PIN diode in reverse bias

4.1 ANTENNA DESIGN

TOP VIEW

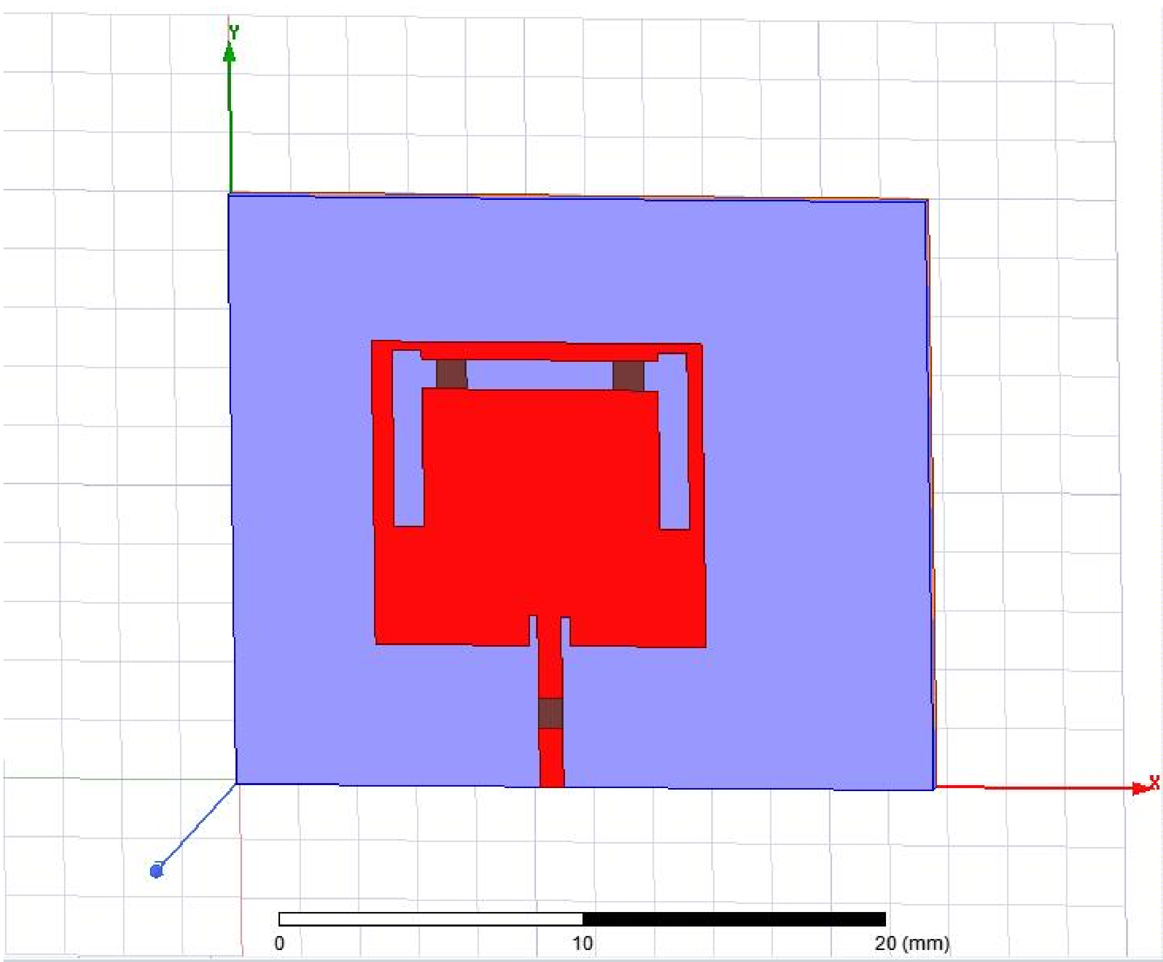

Fig 4.3 Top View of proposed antenna

The above figure is the top view of proposed antenna in HFSS

BOTTOM VIEW:

Fig 4.4 Bottom View of proposed antenna

The above figure is the bottom view of proposed antenna in HFSS

4.2 PERFORMANCE ANALYSIS

It has been observed that frequency reconfiguration of the proposed micro strip slot antenna is obtained by positioning PIN diodes as switch on the slots. The proposed reconfigurable antenna resonates frequencies from 3.30 to 10 GHz respectively.

Table 4.1 summarizes the different switching conditions of the diodes, frequencies and the corresponding return loss.

FREQUENCY AND RETURN LOSS FOR DIFFERENT DIODE SWITCHING CONDITIONS

S. No	Diode 1	Diode 2	Diode 3	Frequency (GHz)	Return loss(db)
1	off	on	off	6.5,10	-13,-11
2	off	on	on	3.3,7.1,9.8	-11,-29,-15
3	on	off	on	6.58,11.7	-30,-11
4	on	off	off	5.9	-31

Table 4.1: The above given table is the frequency and return loss for different diode switching conditions.

4.3 RETURN LOSS PLOT

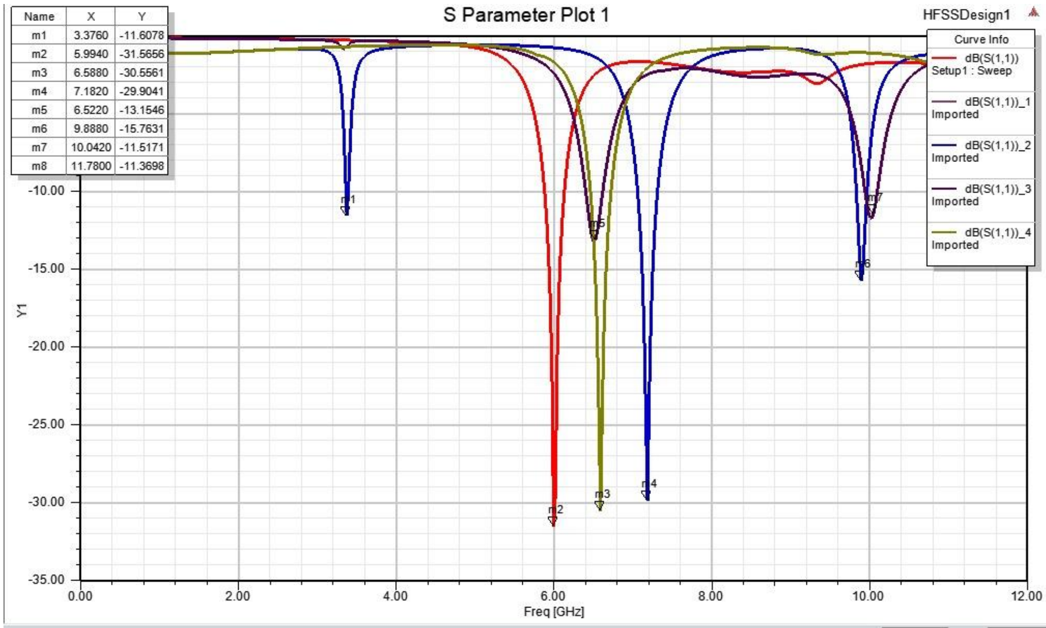

Fig 4.5 Return Loss Plot

The return loss for all the simulated frequencies are less than -10db.

4.4 VSWR PLOT

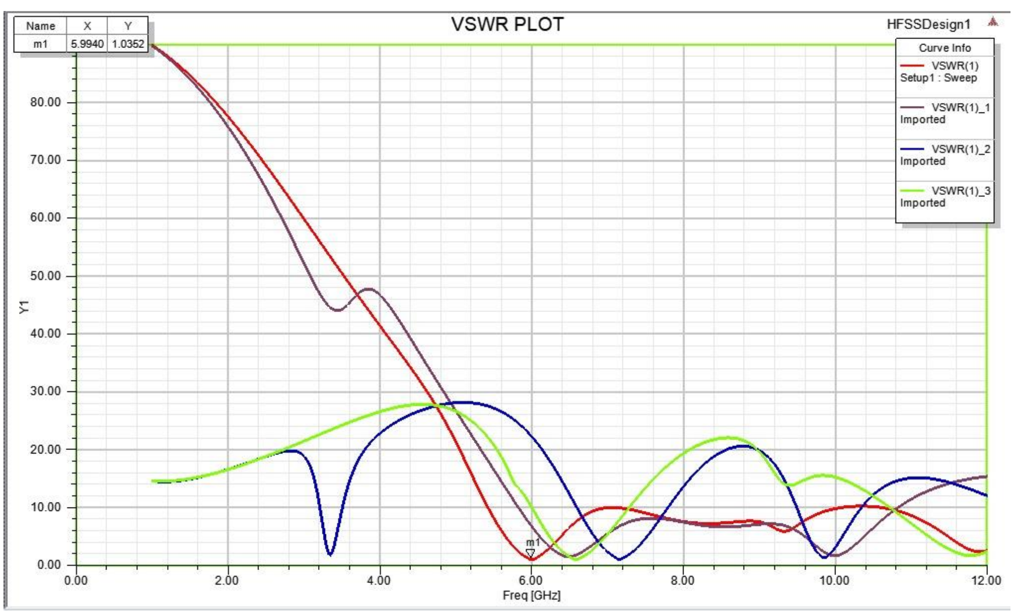

Fig 4.6 VSWR Plot

The VSWR for all the simulated frequencies are below 2.

4.5 GAIN PLOT

Different gain plots are simulated for various resonant frequencies

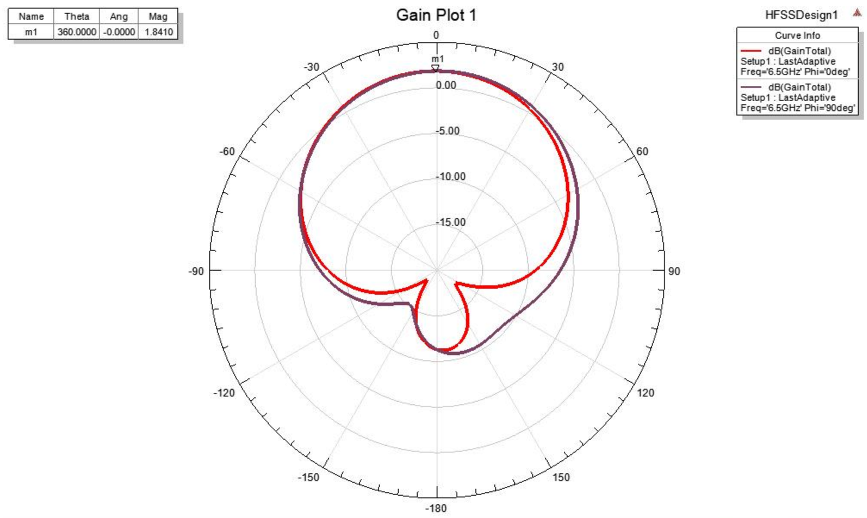

Fig 4.7 Radiation Pattern at 6.5GHz plot

At 6.5GHz the maximum gain is 1.8db

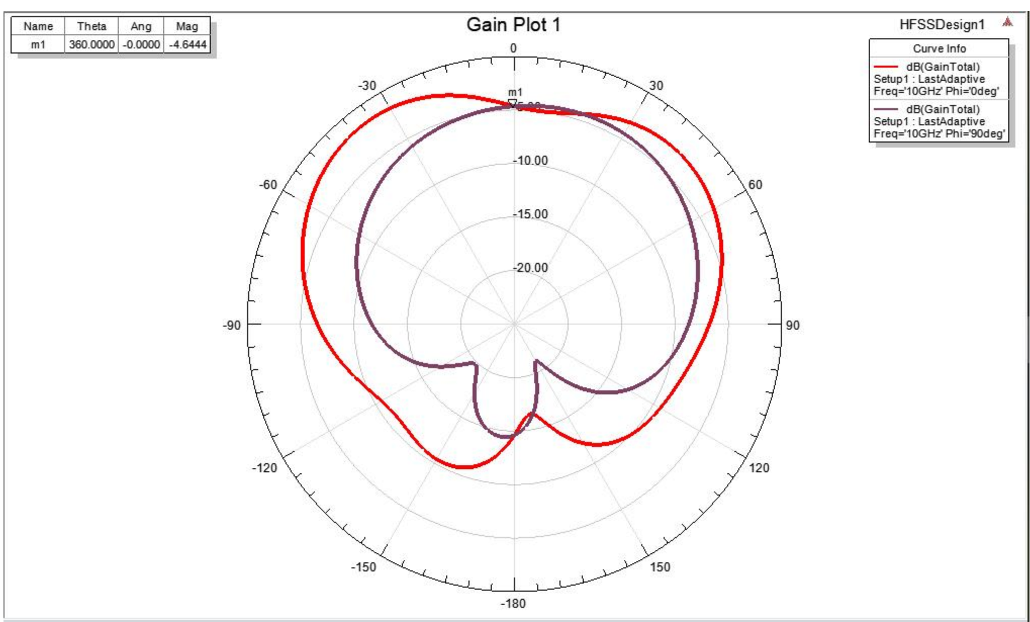

Fig 4.8 Radiation Pattern at 10GHz plot

At 10GHz the maximum gain is -4.6 db

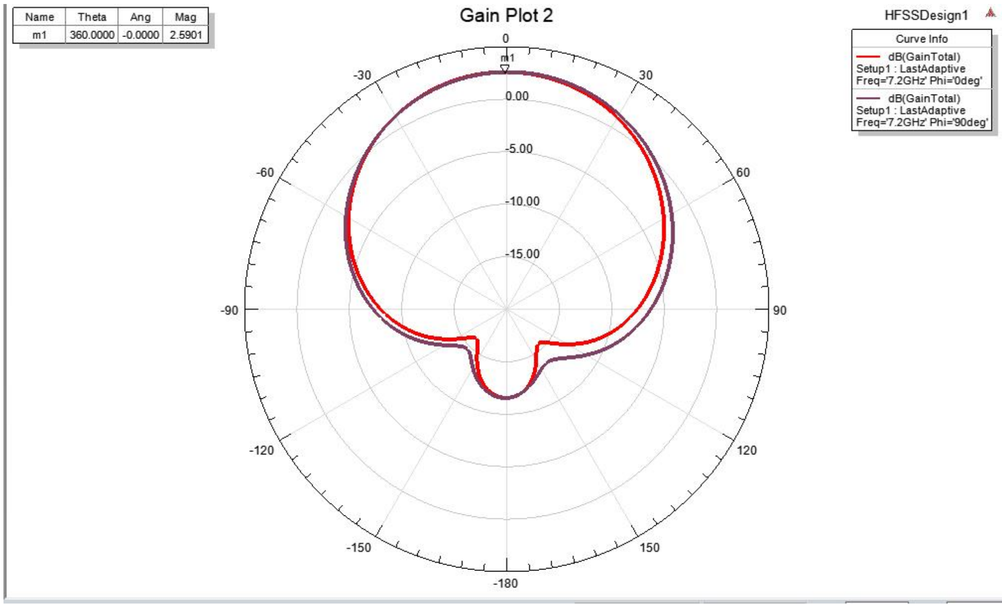

Fig 4.9 Radiation Pattern at 7.2GHz plot

At 7.2GHz the maximum gain is 2.5db

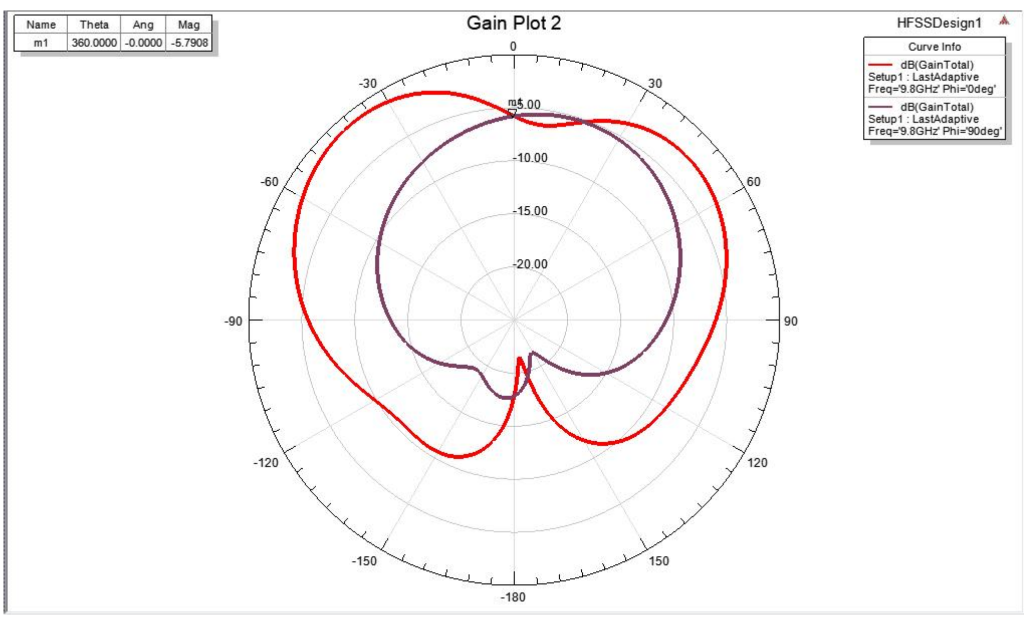

Fig 4.10 Radiation Pattern at 9.8GHz plot

At 9.8GHz the maximum gain is -5.7db

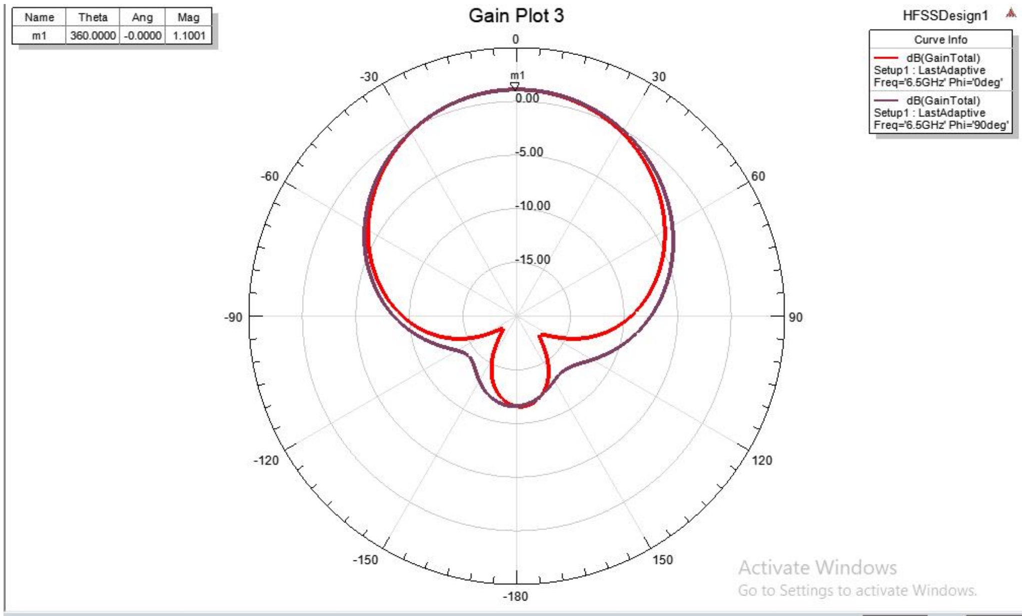

Fig 4.11 Radiation Pattern at 6.58GHz plot

The maximum gain at 6.58GHz is 1.1db

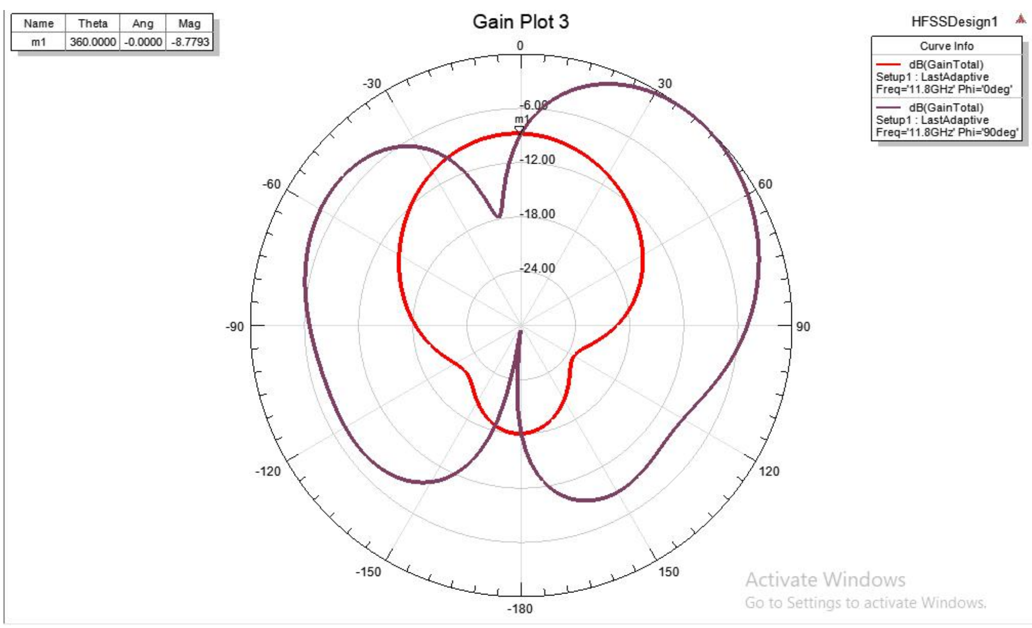

Fig 4.12 Radiation Pattern at 1.8GHz plot

At 1.8GHz the maximum gain is -8.77db

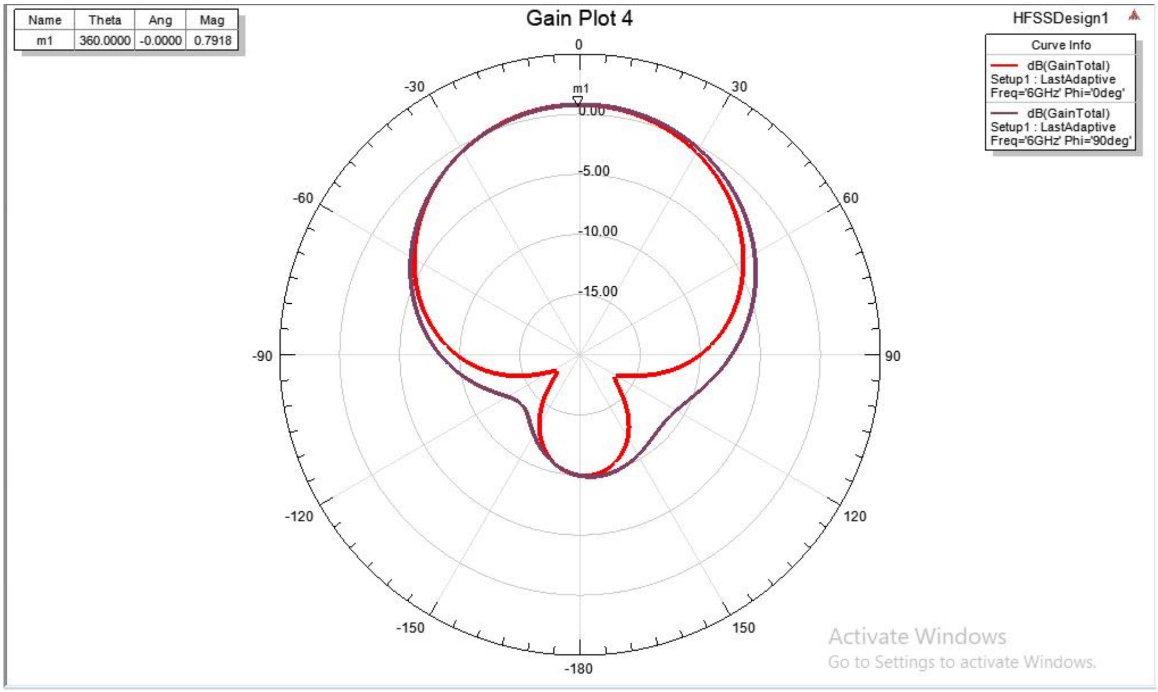

Fig 4.13 Radiation Pattern at 6GHz plot

At 6GHz the maximum gain is 0.79db

4.6 3D POLAR PLOTS

3D gain plots are simulated for various resonant frequencies .We obtained a maximum gain of 5db.

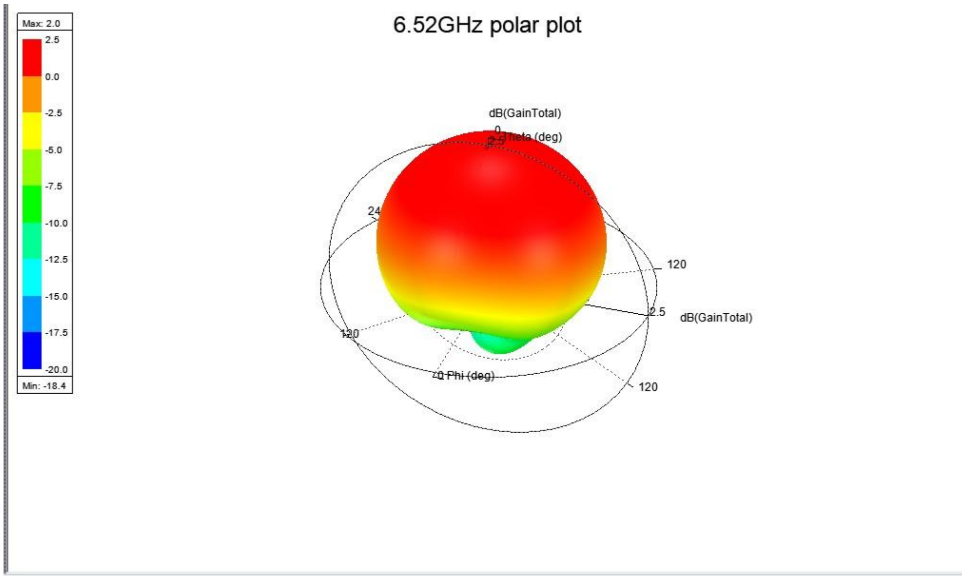

Fig 4.14 6.52GHz polar plot

At frequency 6.52GHz the maximum gain is 2.5db

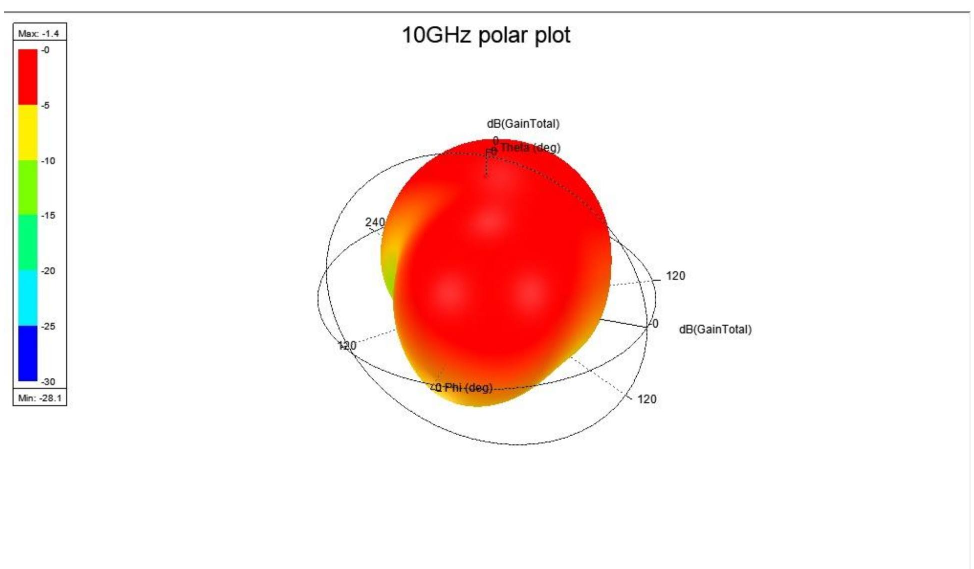

Fig 4.15 10GHz polar plot

At frequency 10GHz the maximum gain is -1.4db

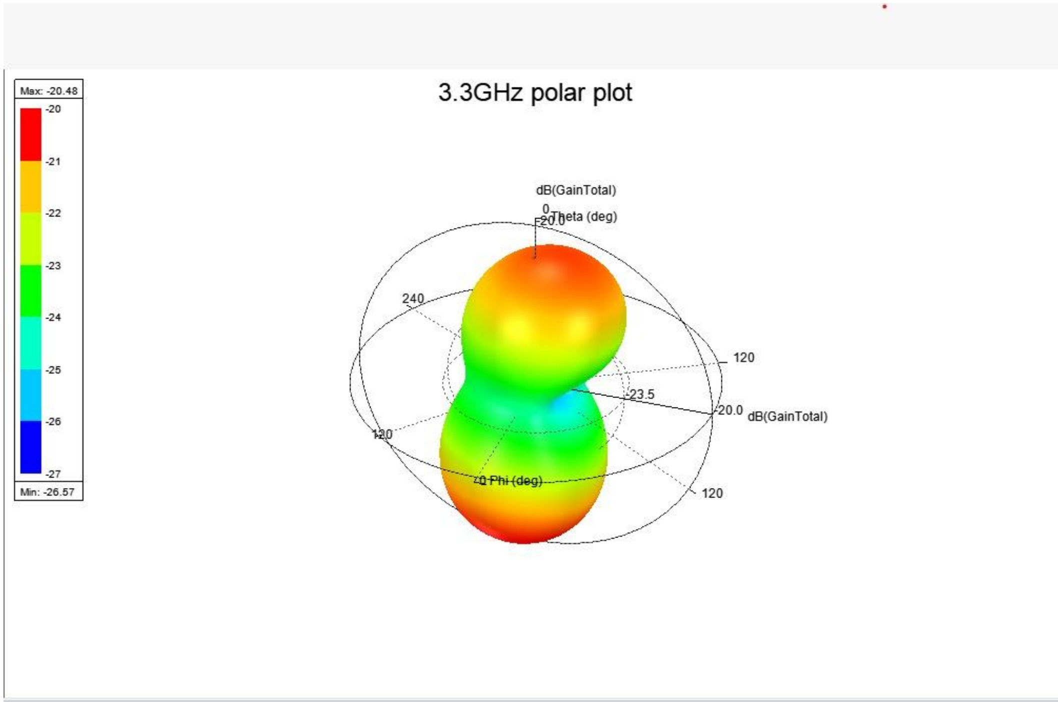

Fig 4.16 3.3GHz polar plot

At frequency 3.3GHz the maximum gain is -20db

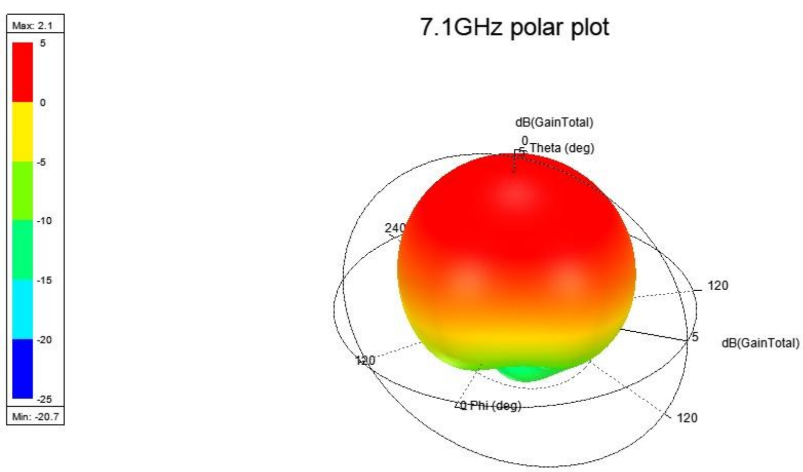

Fig 4.17 7.1GHz polar plot

At frequency 7.1GHz the maximum gain is 2.1db

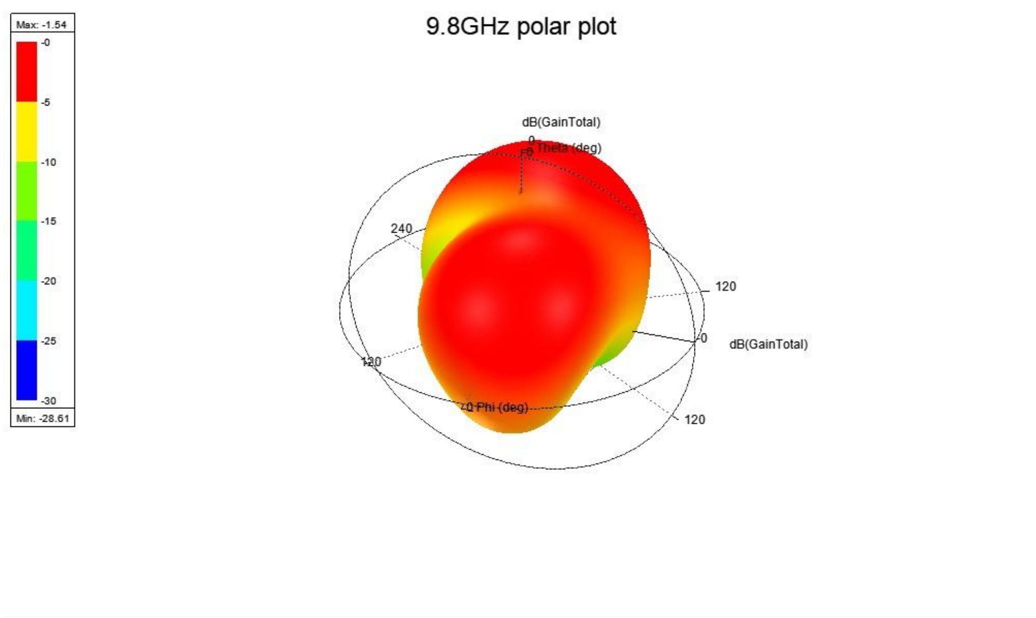

Fig 4.18 9.8GHz polar plot

At frequency 9.8GHz the maximum gain is-1.5db

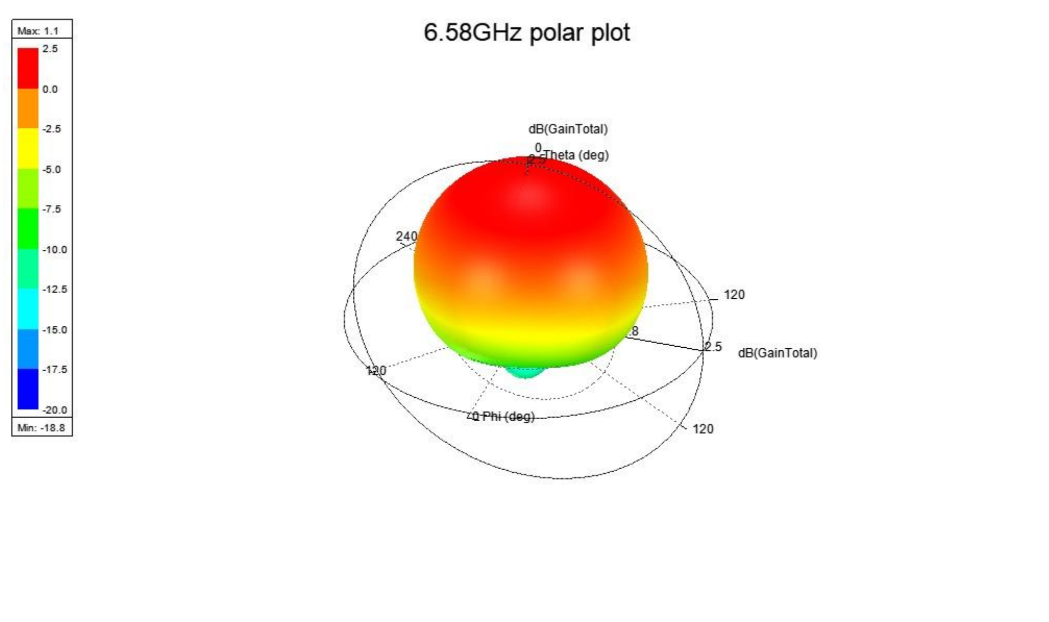

Fig 4.19 6.58GHz polar plot

At frequency 6.58GHz the maximum gain is 1.1db

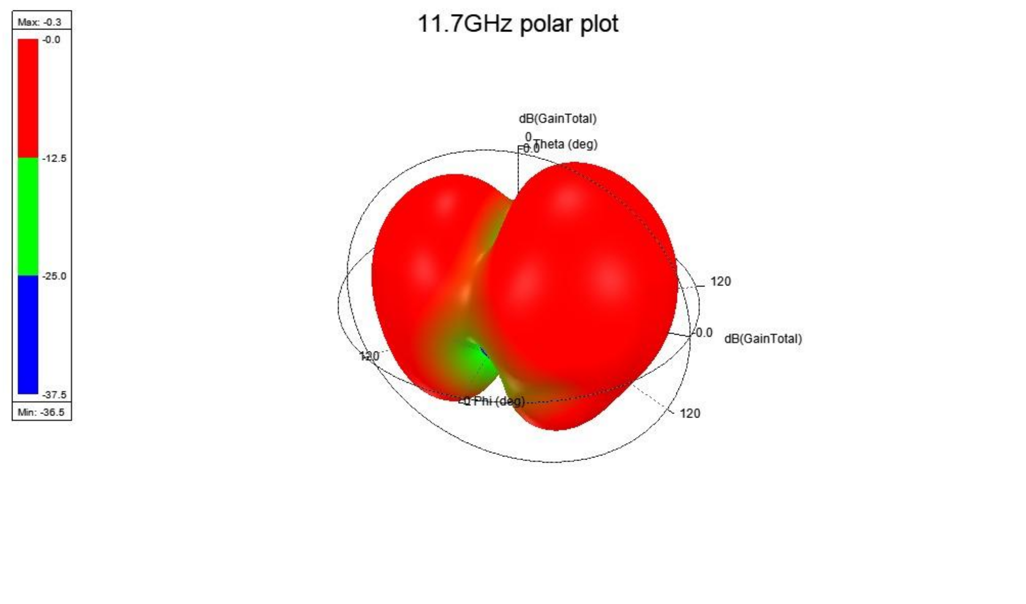

Fig 4.20 11.7GHz polar plot

At frequency 11.7GHz the maximum gain is -0.3db

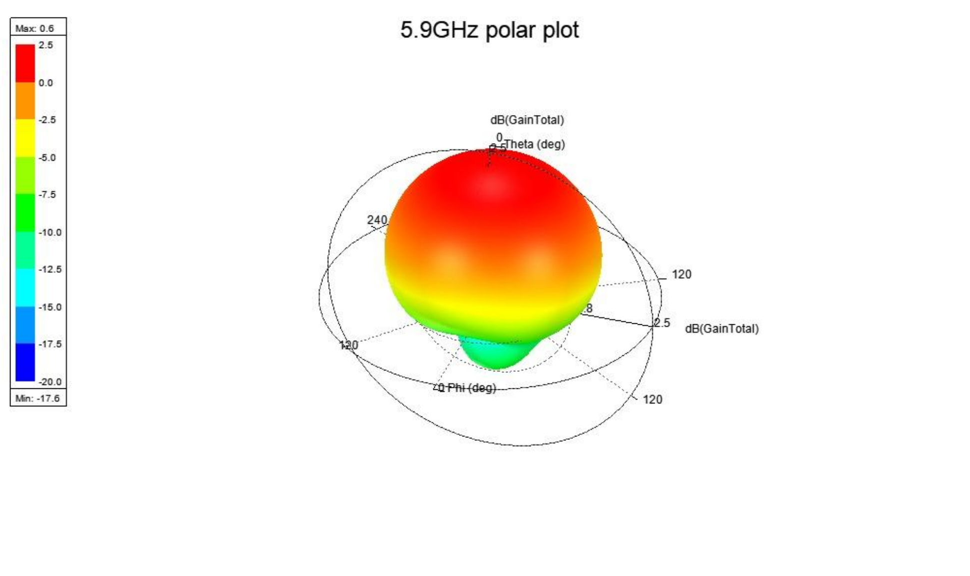

Fig 4.21 5.9GHz polar plot

At frequency 5.9GHz the maximum gain is 0.6db

RESULTS

The following table depicts the various antenna parameters like frequency, return loss, gain and VSWR. All are under permissible values.

S.NO	Frequency (GHz)	Return loss (db)	Gain (db)	VSWR
1	6.5	-13	1.8	1.1
2	10	-11	-4.6	1.2
3	3.3	-11	-2	2
4	7.1	-29	2.59	1
5	9.8	-15	-4	1.3
6	6.58	-30	1.1	1
7	11.7	-11	-5	1.5
8	5.9	-31	0.7	1

Table 4.2: Results

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 CONCLUSION

A new design of the frequency re-configurable antenna for 5G applications is presented here. The proposed antenna consists of a U shaped slot on the patch with the RF PIN diodes placed on the slot. The antenna radiates at eight different frequency bands for different switching conditions. This antenna meets the optimum value of VSWR (voltage standing wave ratio) and the return loss. This antenna is compact and it also enhances the bandwidth also. In the future instead of the PIN diode, the reactor diode and RF MEMS switch will be used as a switch and the hardware model of the antenna will be fabricated. The proposed frequency reconfigurable antenna is well suited for the cognitive radio systems.

5.2 FUTURE SCOPE

The present work of developing the antenna has been done only up to 11GHz for 5G applications. In future we can develop the antenna for higher frequencies up to 60GHz.This can be designed to provide incredible capabilities, immeasurable data and a technology which can interconnect the whole world without any limits.