DESIGN OF MULTIBAND FREQUENCY RECONFIGURABLE ANTENNA FOR WIRELESS APPLICATIONS

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by

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Under the guidance of

Mrs.B.Deepa

(Assistant Professor)

PRAGNANAM BRAHMA

ANITS

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES
(UGC AUTONOMOUS)
(*Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC with 'A' Grade*)
Sangivalasa, bheemili mandal, visakhapatnam dist.A.P

(2021-2022)

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CERTIFICATE

This is to certify that the project report entitled **"DESIGN OF MULTIBAND FREQUENCY RECONFIGURABLE ANTENNA FOR WIRELESS APPLICATIONS"** submitted by **Sabbisetti Venkatesh (318126512170), Gude Reshma(318126512138), Lingampalli Govardhan(318126512151), Bodepu Vinay Kumar(318126512126)** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics & Communication Engineering** of Andhra University, Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.

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ABSTRACT

To achieve multi frequency or multiple radiation patterns, reconfigurable antennas are preferable in terms of size and complexity. In this design, a reconfigurable antenna which resonates in multi-bands for wireless applications such as WLAN, Wi-Fi, LTE etc is designed. This design features a slotted wineglass shaped radiating patch with stubs and a rectangular ring type slot having two diodes(D_1,D_2) on the perfect electric ground.Dielectric material used to design the proposed antenna is Neltec substrate.The outer dimension of the antenna is 30 mm x 30 mm x 0.762 mm. Reconfigurability is achieved by changing the electrical equivalent circuit of p-i-n diodes (diode ON/OFF) which results in four different modes of operations. When both D_1 and D_2 are in OFF state, the proposed antenna offers multi-band operations at 2.52 GHz (S band), 4.27 GHz (C band), 8.88 GHz, 10.80 GHz, 11.78 GHz (X band), 14.04 GHz (Ku band). Similarly antenna resonates at 1.43 GHz (L band), 4.89 GHz, 6.48 GHz (C band), 8.89 GHz (X band), 13.71 GHz (Ku band) in OFF-ON case. Meanwhile for ON-OFF case at 3.95 GHz (S band), 6.18 GHz (C band), 8.77 GHz, 11.88GHz(X band), 14.23 GHz(Ku band). Whereas when both the diodes are ON, antenna resonates at 1.71 GHz(L band), 5.04 GHz, 6.17 GHz(C band).

LIST OF FIGURES

CONTENTS

Chapter-1

INTRODUCTION

In this chapter, we discussed about antenna and it's types, also how antenna has it's radiation mechanism and different types of parameters that it constitutes. And then we also discussed about microstrip patch antenna and it's advantages. We have also discussed different types of feeding methods such as microstrip line feed, coaxial feed, aperture coupled feed and proximity coupled feed. And further we discussed about how multiple frequency bands helps in achieving reconfigurability and different types of reconfigurable antennas.

1.1 HISTORY OF ANTENNAS

The first radio antennas were built by Heinrich Hertz, a professor at the Technical Institute in Karlsruhe, Germany. Heinrich Hertz‘s end-loaded half-wave dipole transmitting antenna and resonant half-wave receiving loop operating at $\lambda = 8$ m in 1886.

Hertz was the pioneer and father of radio, his invention remained a laboratory uriosity until 20-year-old Guglielmo Marconi of Bologna, Italy, went on to add tuning circuits, big antenna and ground systems for longer wavelengths, and was able to signal over large distances. In mid-December 1901 he startled the world by receiving signals at St. Johns, Newfoundland, from a transmitting station he had constructed at Poldhu in Cornwall, England.

Guglielmo Marconi‘s square conical antenna at Poldhu, England, in 1905 for sending transatlantic signals at wavelengths of 1000s of meters is shown in Figure.1.1 below. Rarely has an invention captured the public imagination as Marconi‘s wireless did at the beginning of the 20th century. With the advent of radar during World War II, centimeter wavelengths became popular and the entire radio spectrum opened up to wide usage.

Thousands of communication satellites bristling with antennas now circle the earth in low, medium, and geostationary orbits. The geostationary satellites form a ring around the earth similar to the rings around Saturn. Global Position Satellite (GPS) receiver gives latitude, longitude and elevation to centimeter accuracy anywhere on or above the earth day or night, cloudy or clear.

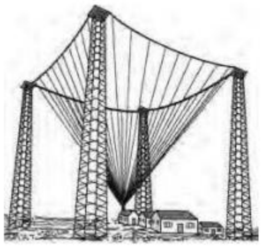


Figure.1.1 Square conical antenna

Very Large Array (VLA) of 27 steerable parabolic dish antennas each 25 m in diameter operating at centimeter wavelengths for observing radio sources at distances of billions of light-years. The array is located at the National Radio Astronomy Observatory near Socorro, New Mexico in 1980. Our probes with their arrays of antennas have visited the planets of the solar system and beyond, responding to our commands and sending back photographs. And our radio telescope antennas operating at millimeter to kilometer wavelengths receive signals from objects so distant that it has taken more than 10 billion years for the signals to arrive.

1.2 INTRODUCTION TO ANTENNAS

Antennas are our electronic eyes and ears on the world. They are our links with space. They are an essential, integral part of our civilization.

An antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves).

In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified. Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones and satellite communications, as well as other devices such as garage door openers, wireless microphones. Very Large Array (VLA) of 27 steerable parabolic dish antennas each 25 m in diameter operating at centimeter wavelengths for observing radio sources at distances of billions of light-years. The array is located at the National Radio Astronomy Observatory near Socorro, New Mexico in 1980 is shown in Figure.1.2 below. Antennas act as transformers between conducted waves and electromagnetic waves propagating freely in space. Their name is borrowed from zoology, in which the Latin word antennae is used to describe the long, thin feelers possessed by many insects.

In wireless communication systems, signals are radiated in space as an electromagnetic wave by using a receiving, transmitting antenna and a fraction of this radiated power is intercepted by using a receiving antenna. An antenna is a device used for radiating or receiving radio waves. An antenna can also be thought of as a transitional structure between free space and a guiding device (such as transmission line or waveguide).

Figure.1.2 Steerable parabolic dish antennas

1.3 TYPES OF ANTENNAS

1.3.1 Wire antennas:

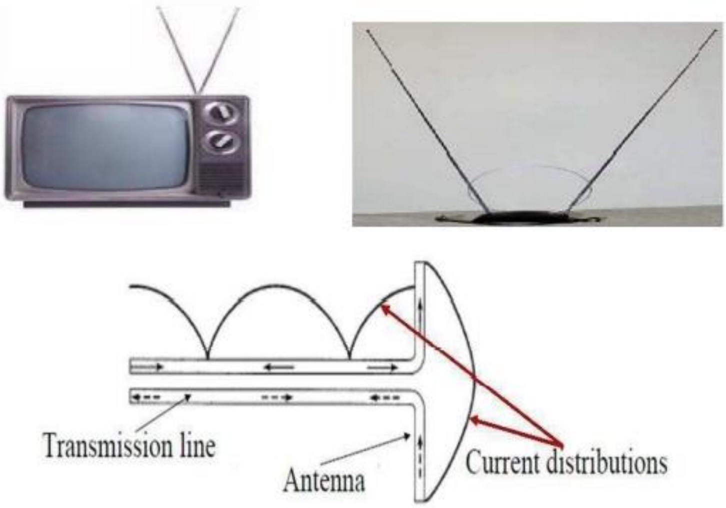


Figure.1.3 Wire antennas

Dipole, monopole, loop antenna, helix antennas:- These were shown in Figure.1.3 and are usually used in personal applications, automobiles, buildings, ships, aircrafts and spacecrafts.

1.3.2 Aperture antennas:

Horn antennas, waveguide opening :- Usually aperture antennas are used in aircrafts and space crafts, because these antennas can be flush.. These are shown in Figure.1.4

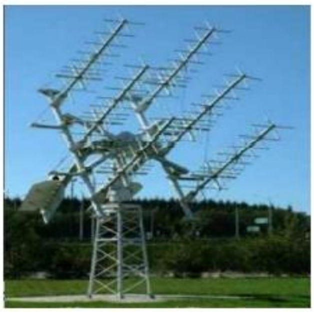


Figure.1.4 Aperture antennas

1.3.3 Reflector antennas:

Parabolic reflectors, corner reflectors :- These are high gain antennas usually used in radio astronomy, microwave communication and satellite tracking. The reflector antennas are shown in Figure.1.5

Figure.1.5 Reflector antennas

1.3.4 Lens antennas:

Convex-plane, convex-convex , convex-concave and concave-plane lenses o These antennas are usually used for very high frequency applications.

1.3.5 Microstrip antennas:

Rectangular, circular etc. shaped metallic patch above a ground plane :- Used in aircraft, spacecraft, satellites, missiles, cars, mobile phones etc and are shown in Figure.1.6.

Figure.1.6 Microstrip antennas

1.3.6 Array antennas:

Yagi-Uda antenna, microstrip patch array, aperture array, slotted waveguide array :- Used for very high gain applications with added advantage, such as controllable radiation pattern.

1.4 RADIATION MECHANISM:

When electric charges undergo acceleration or deceleration, electromagnetic radiation will be produced. Hence it is the motion of charges, that is current is the source of radiation. Here it may be highlighted that, not all current distributions will produce a strong enough radiation for communication.

Antennas radiate or couples or concentrates or directs electromagnetic energy in the desired or assigned direction. An antenna may be isotropic or non directional (omni-directional) and un isotropic or directional.

There accepts include radiation pattern, gain, efficiency, impedance, frequency characteristics, shape size, weight and look at antenna and above all these makes their economic viability. The cost, size and shape makes the main difference on usage of different frequencies.

High gain and Directivity are the basic requirements for the transmitting antennas. Where as low side lobes and large signal to noise ratio are key selection criteria for receiving antennas. Antenna may vary in size from the order of few millimetres(strip antenna) to thousands of feet (dish antennas for astronomical observations) To give a mathematical flavour to it, as we know

$$A = \frac{\mu I dl}{4\pi r}$$

$$dl\frac{dI}{dt} = dlq\frac{dv}{dt} = dlqa$$

$$\boxed{E = -\nabla V - \frac{\partial A}{\partial t} = -\nabla V - \frac{\mu dl}{4\pi r}\frac{\partial I}{\partial t} = -\nabla V - \frac{\mu dl}{4\pi r}qa}$$

As shown in these equations, to create radiation (electric field), there must be a time-varying current dI/dt or an acceleration (or deceleration) a of a charge q. If a charge is moving with an uniform velocity, there is no radiation if the wire is straight, and infinite in extent there is radiation if the wire is curved, bent, discontinuous, terminated. So, it is the current distribution on the antennas that produce the radiation. Usually these current distributions are excited by transmission lines and waveguides as shown in the Figure.1.7.

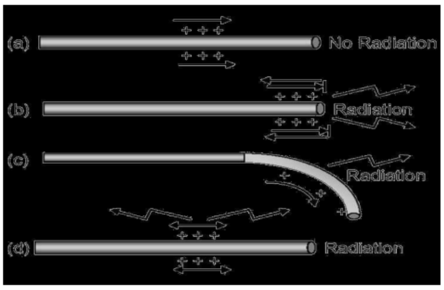


Figure.1.7 Antenna radiation mechanism

1.5 ANTENNA PARAMETERS

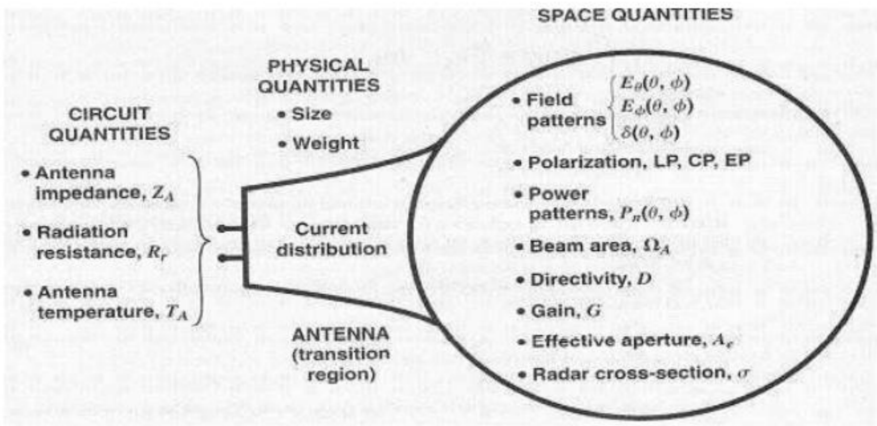


Figure.1.8 Schematic diagram of basic parameters

1) At a given moment, the generator's right side is positive and its left side is negative. A law of physics states that like charges repel each other. Consequently, electrons will flow away from the negative terminal as far as possible while the positive terminal will attract electrons. The distribution curve shows that most current flows in the center and none flows at the ends. The current distribution over the antenna is always the same, regardless of how much or how little current is flowing. However, current at any given point on the antenna will vary directly with the amount of voltage that the generator develops.

2) One-quarter cycle after the electrons begin to flow, the generator develops it; minimum voltage and the current decreases to zero. Although no current is flowing, a minimum number

of electrons are at the left end of the line and a minimum number are at the right end. The charge distribution along the wire varies as the voltage of the generator varies.

1.5.1 Gain:

Gain is a parameter that measures the directionality of a given antenna. An antenna with low gain, emits radiation about same power in all directions, whereas a high gain antenna preferentially radiates in particular directions. Specially the gain, directive gain or power gain of an antenna is defined as the ratio of intensity of the signal radiated by the 11 P antenna in a given direction at an arbitrary distance divided by the intensity radiated at the same distance by a hypothetical isotropic lossless antenna. Since the radiation intensity from a lossless isotropic antenna equals the power into the antenna divided by a solid angle of 4π Steradians,

$$Gain = \frac{4\pi \, radiation \, intensity}{total \, input(transmitted)power}$$

Although the gain of an antenna is directly related to its directivity, antenna gain is a measure that considers the efficiency of the antenna as well as its directional capabilities.

1.5.2 Directivity

The directivity of the antenna has been defined as "the radiation intensity in a given direction from the antenna divided by the radiation intensity averaged over all directions". The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. In other words, the directivity of a non isotropic source is equal to the ratio of its radiation intensity in given direction, over that an isotropic source.

$$D = \frac{4\pi U}{P_{rad}}$$

1.5.3 Return Loss(S11)

The Return Loss (RL) is a parameter that indicates the amount of power that is lost to the load and does not return as a reflection. Waves are reflected leading to the formation of standing waves, when the transmitter and antenna impedance do not match. Hence the RL is a parameter to indicate how well the matching between the transmitter and antenna has taken place. The RL is given by:

$$S11(dB) = 10log_{10} \frac{Pi}{P_r}$$

1.5.4 Polarization

Antenna polarization is an important consideration when selecting and installing antenna. Because radiation property of an antenna depends on the antenna polarization and if polarization is not synchronized between transmitting and receiving antenna even resonant frequency are perfectly matched still the signals will not be received by receiving antenna. The electric field or "E" plane determines the polarization or orientation of the wave. An antenna is vertically linear polarized when its electric field is perpendicular to the Earth's surface. Horizontally linear polarized antenna, have their electric field parallel to the Earth's surface. In a circularly polarized antenna, the plane of polarization rotates in a corkscrew pattern making one complete revolution during each wavelength. A circularly polarized wave radiates energy in the horizontal, vertical plane as well as in every plane in between. If the rotation is clockwise looking into the direction of propagation, the sense is called right-hand-circular (RHC) polarization. If the rotation is counter clockwise, the sense is called left-hand-circular (LHC) polarization. Polarization is an important design consideration. The polarization of each antenna in a system should be properly aligned. Maximum signal strength between stations occurs when both stations are using identical polarization.

1.5.5 Voltage Standing Wave Ratio(VSWR)

As electromagnetic waves travel through the different parts of the antenna system, from the source to the feed line to the antenna and finally to free space, they may encounter differences in impedance at each interface. Depending on the impedance match, some fraction of the wave's energy will reflect back to the source, forming a standing wave pattern in the feed line. The ratio of the maximum power to the minimum power in the wave can be measured and it is called the voltage standing wave ratio (VSWR). A VSWR of 1:1 is ideal. A VSWR of 1.5:1 is considered to be marginally acceptable in low power applications. Minimizing impedance differences at each interface will reduce the VSWR value and maximize power transfer through each part of the system. The VSWR can be expressed as:

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

1.5.6 Bandwidth

The bandwidth is the antenna operating frequency band within which the antenna performs as desired. The bandwidth of a broadband antenna can be defined as the ratio of the higher to lower frequencies of acceptable operation. In other words, the frequency over which the antenna will perform satisfactorily i.e. it's one or more characteristics have acceptable values between the bandwidth limits. The absolute bandwidth (ABW) is defined as the difference of the two edges and the fractional bandwidth (FBW) is designated as the percentage of the frequency difference over the centre frequency, given as

$$ABW = f_L - f_H$$

$$FBW = 2\frac{f_H - f_L}{f_H + f_L}$$

1.5.7 Radiation Pattern

The radiation pattern of an antenna is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization.” Various parts of a radiation pattern are referred to as lobes. Lobes are sub classified into major lobe, minor lobe, side lobe and back lobe. A major lobe (also called main beam) is defined as “the radiation lobe containing the direction of maximum radiation.” A minor lobe is any lobe except a major lobe. A side lobe is “a radiation lobe in any direction other than the intended lobe.” (Usually a side lobe is adjacent to the main lobe and occupiesthe hemispherein the direction of the main beam.) 14 A back lobe is “a radiation lobe whose axis makes an angle of approximately 180° with respect to the beam of an antenna. The radiation pattern in 3D plane is shown in the Figure.1.9

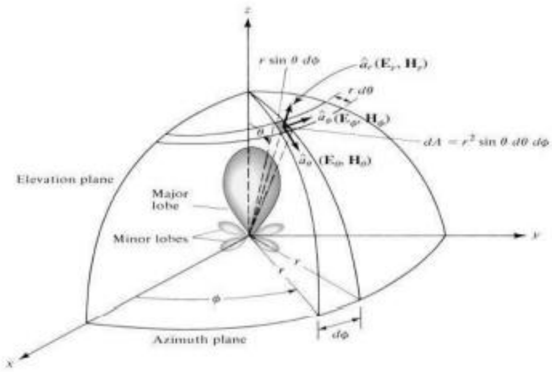


Figure.1.9 Radiation pattern in 3D plane of an antenna

1.6 MICROSTRIP PATCH ANTENNA

Deschamps proposed the concept of microstrip patch antennas in 1953. The first patent of a microstrip antenna design was awarded to Gutton and Baissinot in France in 1955. In the early 1970's the first practical microstrip antennas were fabricated by Munson and Howell .Present-day system requirements such as compact, light weight, low profile conformal antennas that can be directly integrated into a variety of microwave circuits are an important factor in the development of printed antennas. Their low cost and ease of fabrication on printed circuit board make them more attractive than the traditionally used lumped element antennas. Microstrip antennas may be made of any geometrical shape and dimension.

A microstrip patch antennas a radiating patch on one side of a dielectric substrate having very small thickness and has an infinite ground plane on the other side as shown in Figure.1.10. Dielectric materials may be considered as the backbone of microstrip antennas. The patch is generally made of conducting material such as gold or copper and the patch can take any possible shape.

On the dielectric substrate the radiating patch and the feed line are usually photo etched.

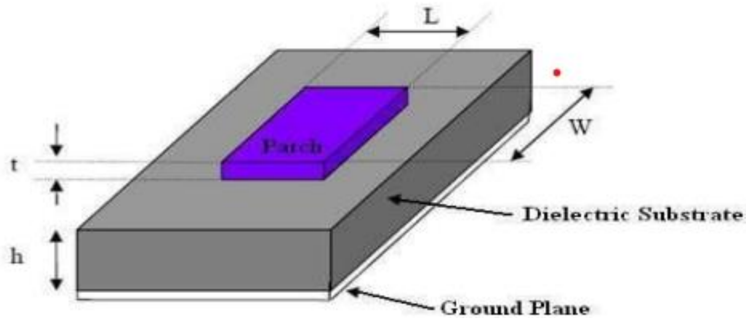


Figure.1.10 Microstrip patch antenna

For simplified analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other regular shape as shown in Figure.1.11. Rectangular patches are the most utilized patch geometry. To design a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. Thickness of patch is selected such that $t << \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$. Fringing fields between the patch edge and the ground plane is main parameter for radiation in microstrip patch antennas. A thick dielectric substrate is required for good antenna performance.

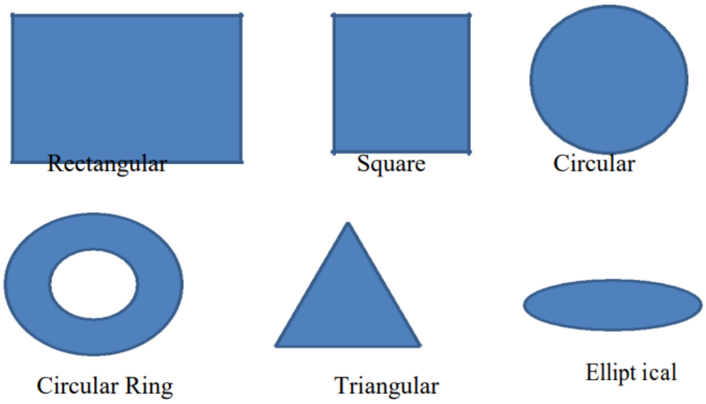


Figure.1.11 Shapes of antenna

1.6.1 ADVANTAGES OF MICROSTRIP PATCH ANTENNA

Microstrip patch antennas found attention of scientific community due to its inherent well-known advantages over other conventional antenna structures. Some of their principal advantages are given below:

- Light weight and low volume.
- Low fabrication cost and readily amenable on mass production.
- The antennas may be easily mounted on missiles and satellites without major alteration.
- Linear and circular polarizations are possible with simple changes in feed position.
- The antennas have low scattering cross section.
- No cavity backing is required.
- Capable of dual and triple frequency operations.
- Feedlines and matching networks may be fabricated simultaneously with antenna structure.

1.6.2 DISADVANTAGES OF MICROSTRIP PATCH ANTENNA

As compared to conventional antennas, microstrip patch antennas suffer from many drawbacks, some of them are

- Due to losses in the dielectric substrate result in low efficiency.
- Low gain.
- Low power handling capacity.
- Poor radiation pattern due to surface waves which travel within the substrate and scatter at surface discontinuities.
- Require quality substrate and good temperature tolerance.

1.6.3 APPLICATIONS OF MICROSTRIP PATCH ANTENNA

Some typical system applications which employ microstrip technology are given below:

- Satellite communications
- Aircraft antennas
- Missiles and telemetry
- Missiles Guidance Systems
- Environmental instrumentation and remote sensing
- Biomedical Instruments
- Radar systems
- Satellite navigation receiver

1.7 FEEDING METHODS OF ANTENNA

There are several methods available in literature to feed or transmit electromagnetic energy to a microstrip patch antenna.

The most famous techniques are the microstrip transmission line, coaxial probe feed, aperture coupling and proximity coupling.

The simplest feeding methods to realize are those of the microstrip transmission line and coaxial probe. Both the methods utilize direct contact with the patch to induce excitation. The point of excitation is adjustable, enabling the designer to control the impedance matching between feed and antenna, polarization, mode of operation and excitation frequency.

For direct contact feeds, the better impedance matching is obtained when the contact point is off the centre.

1.7.1 Microstrip Line Feed

A conducting small strip is connected to the edge of the microstrip patch as shown in Figure.1.12. Microstrip feed line is of rectangular shape and having width less than patch. The patch is generally made of conducting material such as gold or copper and the patch can take any possible shape viz. rectangular, square, circular, elliptical and triangular according to the requirement. The substrate is a dielectric material. Dielectric materials may be considered as the backbone of microstrip antennas. On the dielectric substrate the radiating patch and the feed line are usually photo etched.

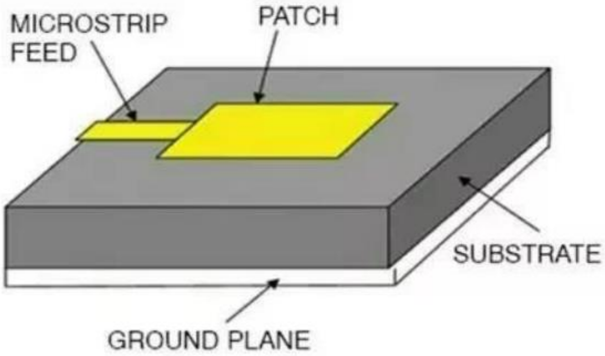


Figure.1.12 Microstrip line feed

A thick dielectric substrate is required for good antenna performance. Substrates with lower dielectric constant are preferred for antenna design for better performance. The ground plane is made up of copper. The ground plane stops the back radiations. The back radiations reduces the efficiency of the antenna.

1.7.2 Coaxial feed

The Coaxial feed or probe feed is a very common technique used for feeding a microstrip patch antenna. As seen from Figure.1.13, the inner conductor of the coaxial connector extends through the dielectric and is connected to the radiating patch, while the outer conductor is connected to the ground plane. Often a hit and trial method is used to obtain the optimum match for the direct contact feeds.

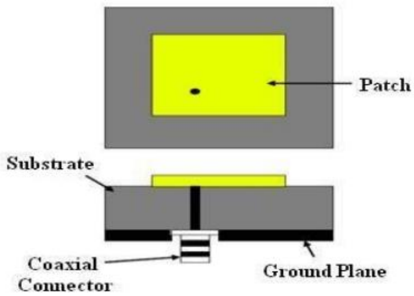


Figure.1.13 Coaxial feed

1.7.3 Aperture Coupled Feed

The aperture-coupled configuration consists of two parallel substrates separated by a ground plane. Excitation of the patch is accomplished by coupling energy from a microstrip line through a small aperture in the ground plane as shown in Figure.1.14.

With this arrangement, the microstrip feed is designed on a thin-high dielectric constant substrate, which tightly binds the field lines while the patch is designed on a thick low dielectric constant substrate.

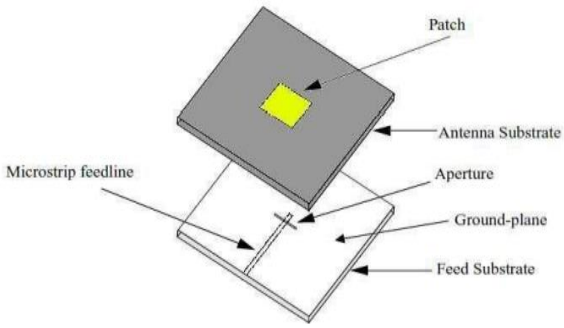


Figure.1.14 Aperture coupled feed

The ground planes isolate the feed from the patch and thus minimize spurious radiation from the feed, which would interfere with the antenna pattern. Therefore, the design of the patch and the transmission line are independent. The major disadvantage of this feed method is that it is difficult to fabricate due to multiple layers, which increase the antenna thickness. This feeding scheme also provides narrow bandwidth.

1.7.4 Proximity Coupled Feed

Proximity coupled feed technique is also known as the electromagnetic coupling scheme. As shown in Figure.1.15, the proximity-coupled scheme operates in a manner similar to that of the aperture-coupled configuration except the ground plane is removed. In this method two dielectric substrates are used such that the feed line is in between the two substrate and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth, due to overall increase in the thickness of the microstrip patch antenna. Matching can be achieved by controlling the length of the feed line. The major disadvantage of this feed technique is that it is difficult to fabricate because of the dielectric layers need proper alignment.

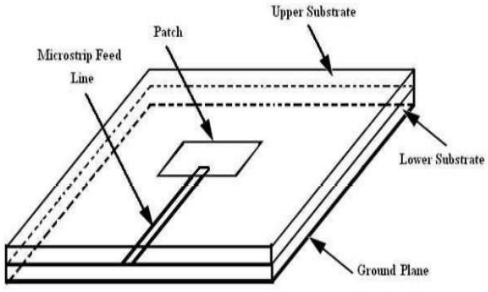


Figure.1.15 Proximity coupled feed

1.8 MULTI-BAND FREQUENCY

In recent times, there has been an explosive growth in wireless commu-nications. With a rapid advance in wireless communication systems andan increasing importance of other wireless applications, antennas whichare designed to address more than one band/service at time are in greatdemand in both commercial as well as military sectors. This boomingdemand has resulted in a renewed interest in multiband antennas.

A multiband antenna is an antenna designed to operate in multiple bands of frequencies. Multiband antennas use a design in which one part of the antenna is active for one band, while another part is active for a different band and this is represented as shown in Figure.1.16.

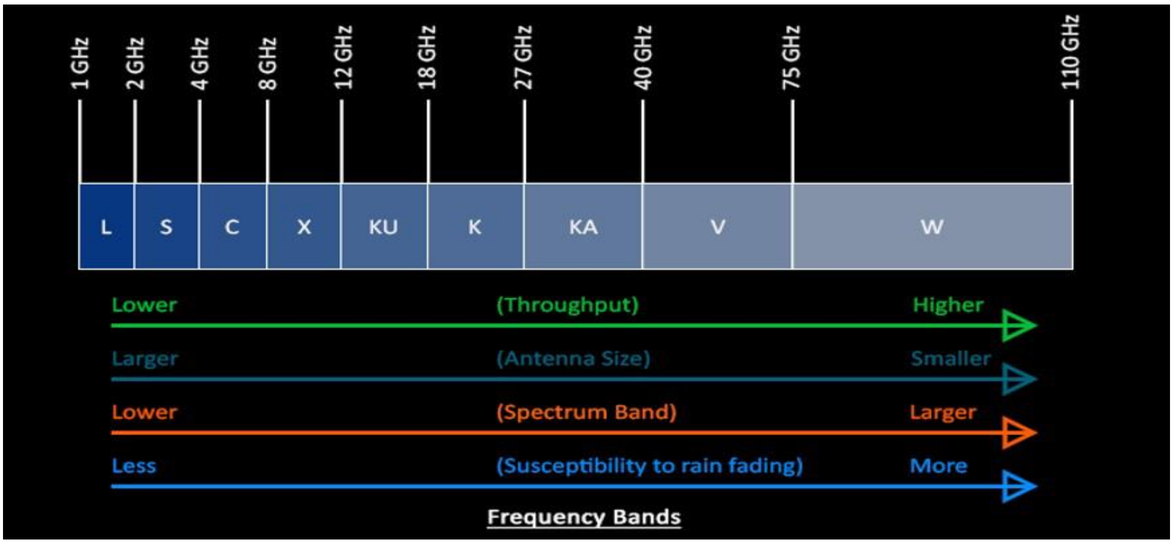


Figure.1.16 Frequency bands

L-band (1–2 GHz)

Global Positioning System (GPS) carriers and also satellite mobile phones, such as Iridium; Inmarsat providing communications at sea, land, and air; WorldSpace satellite radio.

S-band (2–4 GHz)

Weather radar, surface ship radar, and some communications satellites, especially those of NASA for communication with ISS and Space Shuttle. In May 2009, Inmarsat and Solaris mobile (a joint venture between Eutelsat and Astra) was awarded each a 2×15 MHz portion of the S-band by the European Commission.

C-band (4–8 GHz)

Primarily used for satellite communications, for full-time satellite TV networks or raw satellite feeds. Commonly used in areas that are subject to tropical rainfall, since it is less susceptible to rain fade than Ku band (the original Telstar satellite had a transponder operating in this band, used to relay the first live transatlantic TV signal in 1962).

X-band (8–12 GHz)

Primarily used by the military. Used in radar applications including continuous-wave, pulsed, single-polarisation, dual- polarisation, synthetic aperture radar, and phased arrays. X-band radar frequency sub-bands are used in civil, military and government institutions for weather monitoring, air traffic control, maritime vessel traffic control, defense tracking, and vehicle speed detection for law enforcement.

Ku-band (12–18 GHz)

Used for satellite communications. In Europe, the Ku-band downlink is used from 10.7 GHz to 12.75 GHz for direct broadcast satellite services, such as Astra.

Ka-band (26–40 GHz)

Communications satellites for close up high resolutions applications, uplink in either the 27.5 GHz and 31 GHz bands, close-range targeting radars on military aircraft.

1.8.1 APPLICATIONS OF MULTI BAND FREQUENCY

WiMAX is a technology based on the IEEE 802.16 specifications to enable the delivery of last-mile wireless broadband access as an alternative to cable and DSL. The design of WiMAX network is based on the following major principles −

Spectrum − able to be deployed in both licensed and unlicensed spectra.

Topology − supports different Radio Access Network (RAN) topologies.

Interworking − independent RAN architecture to enable seamless integration and interworking with WiFi, 3GPP and 3GPP2 networks and existing IP operator core network.

IP connectivity − supports a mix of IPv4 and IPv6 network interconnects in clients and application servers.

Mobility management − possibility to extend the fixed access to mobility and broadband multimedia services delivery.

WiMAX has defined two MAC system profiles the basic ATM and the basic IP. They have also defined two primary PHY system profiles, the 25 MHz-wide channel for use in (US deployments) the 10.66 GHz range, and the 28 MHz wide channel for use in (European deployments) the 10.66 GHz range. The WiMAX technical working group is defining MAC and PHY system profiles for IEEE 802.16a and HiperMan standards. The MAC profile includes an IP-based version for both wireless MAN (licensed) and wireless HUMAN (licence-exempt).

Chapter-2

RECONFIGURABLE ANTENNA

2.1 Introduction to Reconfigurable Antenna

Antennas are necessary and critical components of communication and radar systems. Arguably, nine different types of antennas have proliferated during the past 50 years in both wireless communication and radar systems. These nine varieties include dipoles, monopoles. loop antennas, slot/horn antennas, reflector antennas. Microstrip antennas, log periodic antennas, helical antennas, dielectric/lens antennas and frequency-independent antennas. Each category possesses inherent benefits and detriments that make them more or less suitable for particular applications. When faced with new system design guidelines as starting points to develop new structures that often produce acceptable results.

Reconfigurable antennas are capable of dynamically altering their frequency, polarization, and radiation properties in a controlled and reversible manner. They modify their geometry and behaviour to maximize the antenna performance in response to changes in their surrounding conditions. To implement a dynamical response, they employ different mechanisms such as PIN diodes, varactors, radio-frequency microelectromechanical systems (RF-MEMS), field effect transistors (FETs), parasitic pixel layers, photoconductive elements, mechanical actuators, metamaterials, ferrites, and liquid crystals. These mechanisms enable intentional distribution of current on the antenna surface producing reversible modification of their properties.

A reconfigurable antenna provides the same functionality as that given by multiple single-purpose antennas. This offers saving in costs, weight, volume, and maintenance/repair resources. The reconfigurable antenna for wireless applications is shown in Figure.2.1.

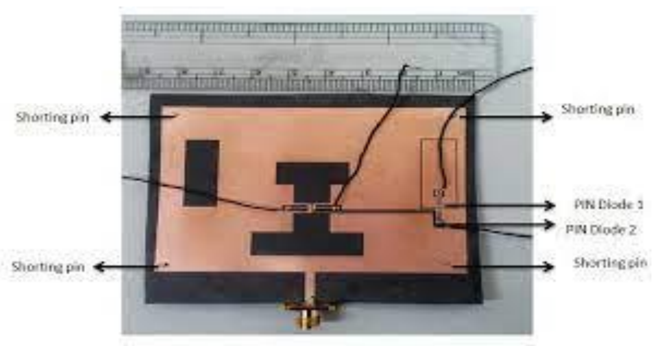


Figure.2.1 Reconfigurable antenna for wireless communications

2.1.1 NECESSITY OF RECONFIGURABILITY

Let us consider two general application areas, single-element scenarios and array scenarios, In single-element scenarios an antenna used in portable wireless devices, such as a cellular telephone, a personal digital assistant, or a laptop computer.

Single antenna typically used in these devices are monopole or microstrip antenna based and may or may not have multiple - frequency capabilities. Some packages may use two or three antennas for diversity reception on small devices to increase the probability of receiving a usable signal, but usually only one of the antennas is used for transmission. The transmission from the portable device to a base station or other access point is the weakest part of the bidirectional communication link because of the power, size, and cost restrictions imposed by portability.

Moreover, the portable device is often used in unpredictable and/or harsh electromagnetic conditions, resulting in antenna performance that is certainly less than optimal. Antenna reconfigurability in such a situation could provide numerous advantages. For instance, the ability to tune the antenna's operating frequency could be utilized to change operating bands, filter out interfering signals, or tune the antenna to account for a new environment.

If the antenna's radiation pattern could be changed, it could be redirected toward the access point and use less power for transmission, resulting in a significant savings in battery power. The antennas are mostly used in array configuration, feed structures with power dividers/combiners and phase shifters. For instance, current planar phased array radar technology is typically limited in both scan angle and frequency bandwidth as a result of the limitations of the individual array elements and the restrictions on antenna element spacing.

There are several antenna structures that are suitable for implementation of reconfigurable antennas, among them microstrip patch antennas are very attractive structures for various types of reconfigurable antennas, all such antennas are usually equipped with switches that are controlled by DC bias signals. Upon toggling the switch between on and off states, the antenna can be reconfigured. The following section describes the design procedure of microstrip patch antenna types presented and different feed types used in this dissertation.

2.2 CLASSIFICATION OF RECONCONFIGURABLE ANTENNAS

Antennas Based on the operational properties dynamically adjusted, e.g. frequency of operation, radiation pattern, polarization or a combination of any of these properties, reconfigurable antennas can be classified as follows:

2.2.1 Frequency Reconfigurable Antenna:

Frequency reconfigurable antennas can adjust their frequency of operation dynamically. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna. Frequency reconfiguration is generally achieved by physical or electrical modifications to the antenna dimensions using RF-switches, impedance loading or tunable materials. These antennas can be developed by two mechanisms, electrical or mechanical. The electrical mechanism employs discrete tuning and continuous tuning methods.

2.2.2 Radiation-Pattern reconfigurable antenna:

Radiation pattern reconfigurability is based on the intentional modification of the spherical distribution of the radiation pattern. Pattern reconfigurable antennas are usually designed using movable/rotatable structures or switchable in reactively loaded capacitive elements for the intentional modification of the spherical distribution of radiation pattern.

2.2.3 Polarization Reconfigurable Antenna:

These antennas use switching between different polarizations, i.e. from linear polarization to left hand circular polarization (LHCP) and righthand circular polarization (RHCP), using multi modes structures. To reduce the polarization mismatch, losses in portable devices, switching between horizontal, vertical and circular polarizations are needed.

2.2.4 Compound Reconfigurable Antennas:

These antennas use simultaneous tuning of several antenna parameters, e.g. frequency and radiation pattern, for independent reconfiguration of operating frequency, radiation pattern and polarization. The most common application of compound reconfiguration is the combination of frequency agility and beam-scanning to provide improved spectral efficiencies. Compound reconfigurability is achieved by combining in the same structure different single -parameter reconfiguration techniques or by reshaping dynamically a pixel surface.

2.3 RECONFIGURATION TECHNIQUES

Based on the requirement on the reconfiguration property of the antenna, there are four major types of reconfiguration techniques: electrical, optical, mechanical and smart material.

2.3.1 Electrical Reconfiguration:

Electrical reconfiguration techniques are based on the use of switches to connect or disconnect antenna parts and redistribute the currents by altering the radiated fields of the antenna's effective aperture. Radio-frequency microelectromechanical systems (RF-MEMS), PIN diodes, varactor diodes, or field effect transistors (FETs) are integrated into the antenna to redirect their source currents. RF-MEMS switches based antennas rely on the mechanical movement of the switches to achieve reconfiguration. Many antenna designs have resorted to RF-MEMS to reconfigure their performance.

PIN DIODES

A PIN diode is a diode with a wide, undoped intrinsic semiconductor region between a p-type semiconductor and an n-type semiconductor region as shown in Figure.2.2. The wide intrinsic region makes the PIN diode a fast switch, photo detectors, and high voltage power electronics applications. PIN diodes are widely used as the switching components in different wireless systems. The PIN diode needs a high tuning speed, a high bias current in the ON-state and a high power handling capacity. it is very reliable and extremely low-cost which makes it a good choice for the reconfiguration technique.

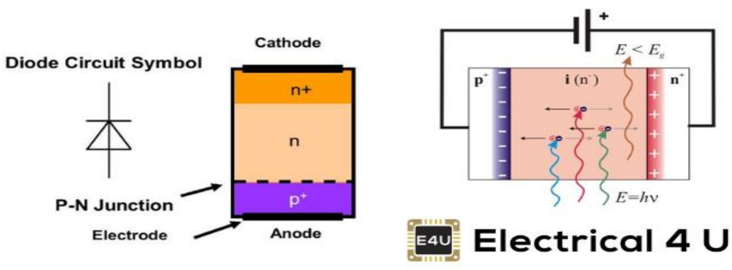


Figure.2.2 Pin diode

TUNABLE VARACTORS

Varactors are used as voltage-controlled capacitors. By changing the voltage levels of the varactor, its capacitance changes, which leadsto tune the antenna performance. Usage of varactors in reconfigurable designs helps to achieve the frequency tuning function. The varactor is nonlinear with a low dynamic range. It also requires a complex bias circuitry. When compared with other active elements such as a PIN diode or MEMS, it has a small current flow and continuous tuning characteristics. Varactor is shown in Figure.2.3. Voltage controlled oscillators have many applications such as phase-locked loops are used for the frequency synthesizers that tune many radios, television sets, and cellular telephones. The equation for capacitance is: $A\ C = \varepsilon r \varepsilon o$ A/D.

Where C is the capacitance in Farads. A is the area of each plate measured in square meters. εr is the relative permittivity of the insulator. $\varepsilon 0$ is the permittivity of free space. D is the separation between the plates in meters.

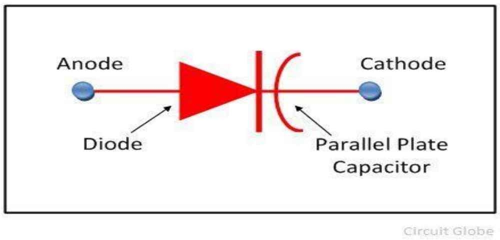


Figure.2.3 Varactor

MEMS

MEMS switches are devices which operate by the use of mechanical movement to achieve a short or open circuit in RF circuits as shown in Figure.2.4. MEMS switches can be designed in different configurations based on signal path, the required force for mechanical movement can be obtained by different mechanisms for actuation such as electrostatic and magnetostatics. RFMEMS switches that are able to handle up to 20 W. These have applications in radar system, network analyser, satellite communication systems and base stations. An RFMEMS shunt switch is a type of MEMS switch, It is a series switch, which consists of a suspended movable thin metal bridge over the centre conductor. MEMS switches for RF applications operate through short and open circuits to transmit signals.

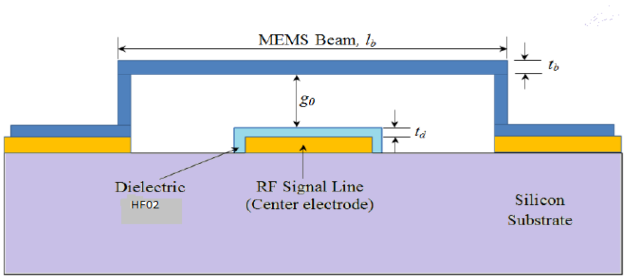


Figure.2.4 MEMS

2.3.2 Optically Reconfiguration

Optically reconfigurable antenna comes under the class of radiating elements that has the capability of changing the radiation properties with the use of switches which may be optical activation of silicon switches of reactive elements. The metal wires that may interfere with the antenna's radiation characteristics can be eliminated in case of optically controlled devices. The use of additional metallic microstrip or wired biasing lines makes the antenna complex and interference among the required radiation pattern makes the major issues in case of DC controlled microstrip antennas, can be overcome using optically controlled reconfigurable antenna.

2.3.3 Mechanical Reconfiguration:

In mechanical reconfiguration, the main radiator of the antenna can be reconfigured mechanically to provide different characteristics. In contrast to other reconfiguration techniques with the switches, this type of reconfigurable antenna does need active element integration, biasing systems. The performance flexibility of this type of antenna is limited, and it is difficult to provide multi-function reconfigurable characteristics.

In a reconfigurable antenna uses a liquid metal to mechanically reconfigure its performance. By changing the size of channel filling, the operation frequency and impedance bandwidth of the proposed mechanically reconfigurable antenna can be easily tuned for different frequencies.

2.3.4 Reconfiguration Based on Smart Materials

Antennas are also made reconfigurable through a change in the substrate characteristics by using materials such as liquid crystals, dielectric fluids, ferrites or meta surfaces. The change in the material is achieved by a change in the relative electric permittivity or magnetic permeability. In fact, a liquid crystal is a nonlinear material whose dielectric constant can be changed under different voltage levels, by altering the orientation of the liquid crystal molecules. As for a ferrite material, a static applied electric/magnetic field can change the relative material permittivity/permeability. In meta surfaced antenna, the meta surface is placed directly at top of the patch antenna and is rotated. This change the equivalent relative permittivity of the structure by which the resonant frequency of the antenna can be tuned.

2.4 Applications of Reconfigurable Antenna

The advancements in wireless communication applications require new generation of reconfigurable antennas which can adjust to the environments and adopt reconfigurable capabilities as per the surrounding conditions. The reconfigurable antennas are used in cognitive radio system, MIMO systems, satellite communication, biomedical application, military and industrial applications. Some of the applications are presented here.

Chapter-3

HFSS

3.1 Ansys HFSS: (high-frequency structure simulator)

It is a commercial finite element method solver for electromagnetic (EM) structures from Ansys that offers multiple state-of-the-art solver technologies. Each solver in ANSYS HFSS is an automated solution processor for which the user dictates the geometry, properties of the material and the required range of solution frequencies.

Engineers use Ansys HFSS primarily to design and simulate high-speed, high-frequency electronics in radar systems, communication systems, satellites, Advanced Driver Assistance Systems(ADAS), microchips, printed circuit boards, IoT products, and other digital devices and RF devices. The solver has also been used to simulate the electromagnetic behavior of objects such as automobiles and aircraft. ANSYS HFSS allows system and circuit designers to simulate EM issues such as losses due to attenuation, coupling, radiation and reflection.

The benefits of simulating a circuit's high frequency behavior with high accuracy on a computer reduces the final testing and verification effort of the system as well as mitigating the necessity of building costly multiple prototypes, saving both time and money in product development.

HFSS captures and simulates objects in 3D, accounting for materials composition and shapes/geometries of each object. HFSS is one of several commercial tools used for antenna design, and the design of complex radio frequency electronic circuit elements including filters, transmission lines, and packaging. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University. Prof. Cendes and his brother Nicholas Cendes founded Ansoft and sold HFSS stand-alone under a 1989 marketing relationship with Hewlett-Packard, and bundled into Ansoft products. In 1997 Hewlett-Packard acquired Optimization Systems Associates Inc. (OSA), a company John Bandler founded in 1983. HP's acquisition was driven by the HP's need for an optimization capability for HFSS.

After various business relationships over the period 1996–2006, HP (which became Agilent EEs of EDA division) and Ansoft went their separate ways Agilent with the critically acclaimed· FEM Element and Ansoft with their HFSS products, respectively. Ansoft was later acquired by Ansys.

This is a procedure where a structure is subdivided into many smaller subsections called finite elements. The finite elements used by HFSS are tetrahedra, and the entire collection of tetrahedron is called mesh. A solution is found for the fields within the finite elements ,are interrelated so that Maxwell's equations are satisfied across inter-clement boundaries .Yielding a field solution for the entire, original, structure. Once the field solution has been found, the generalized S-matrix solution is determined.

HFSS (High Frequency Structure Simulator) employs versatile solvers and an intuitive GUI to give you unparalleled performance plus deep insight into all your 3D EM problems. Through integration with Ansys thermal, structural and fluid dynamics tools, HFSS provides a powerful and complete multi-physics analysis of electronic products, ensuring their thermal and structural reliability. HFSS is synonymous with gold standard accuracy and reliability for tackling 3D EM challenges by virtue of its automatic adaptive meshing technique and sophisticated solvers, which can be accelerated through high performance computing (HPC) technology.

The Ansys HFSS simulation suite consists of a comprehensive set of solvers to address diverse electromagnetic problems ranging in detail and scale from passive IC components to extremely large-scale EM analyses such as automotive radar scenes for ADAS systems. Its reliable automatic adaptive mesh refinement lets you focus on the design instead of spending time determining and creating the best mesh.

This automation and guaranteed accuracy differentiate HFSS from all other EM simulators, which require manual user control and multiple solutions to ensure that the generated mesh is suitable and accurate. With Ansys HFSS, the physics defines the mesh rather than the mesh defining the physics Ansys HFSS is the premier EM tool for R&D and virtual design prototyping. It reduces design cycle time and boosts your product’s reliability and performance.

3.2 Ansys HFSS Capabilities

Its dependable automated adaptive mesh refinement allows you to concentrate on the design rather than figuring out and designing the right mesh.

Ansys HFSS stands out from all other EM simulators due to its automation and guaranteed accuracy. Other EM simulators require manual user control and numerous solutions to ensure that the generated mesh is suitable and accurate.

3.2.1 HIGH-FREQUENCY ELECTROMAGNETIC SOLVERS:

Simulate the electromagnetic behavior of your products using the premier electromagnetic solver technology.

3.2.2 RELIABILITY AND AUTOMATIC ADAPTIVE MESHING:

In HFSS, meshes are produced automatically, ensuring efficient simulations and highly accurate results.

3.2.3 3D COMPONENTS:

Share 3D simulation-ready components throughout the supply chain and protect your IP.

3.2.4 ADVANCED PHASED ARRAY ANTENNA SIMULATION:

Calculate phased-array antennas with all electromagnetic effects, including element-to-element coupling and critical array edge effects.

3.2.5 HIGH-PERFORMANCE COMPUTING:

Perform bigger, faster and higher fidelity simulations with our groundbreaking HPC methodologies, which are optimized for single multicore machines and scalable to take advantage of full cluster power.

3.2.6 OPTIMIZED USER ENVIRONMENT:

The full-featured 3D solid modeler and layout interface enables you to work in a layout design flow, or to import and edit 3D CAD geometry.

3.3 Ansys HFSS Features

3.3.1 EMI/EMC Analysis:

Engineers may use Ansys Electronics Desktop to diagnose, isolate, and remove EMI and radio-frequency issues (RFI) early in the design cycle by combining the unparalleled precision of

Ansys electromagnetic 3D and 2.5D field solvers with the efficient circuit- and system-level solution in Ansys RF Option.

Users can use Electronics Desktop's seamless workflow, which includes advanced electromagnetic field solvers, to predict EMI/EMC output of electrical devices by dynamically linking them to power circuit simulators. These integrated workflows eliminate expensive repeated EMC qualification checks and redundant design iterations. Engineers may determine the overall performance of their electrical devices and build interference-free designs using several EM solvers designed to resolve a variety of electromagnetic problems, as well as the circuit simulators in Electronics Desktop. Radiated and conducted emissions, susceptibility, crosstalk, RF desense, RF coexistence, cosite, electrostatic discharge, electric fast transients (EFT), blast, lightning strike effects, high intensity fields (HIRF), and radiation hazards are only a few of the issues that need to be addressed (RADHAZ), electromagnetic environmental effects (EEE), electromagnetic pulse (EMP) to shielding effectiveness and other EMC applications.

3.3.2 Radio Frequency Intereference in complex environement:

For modeling mounted antenna-to-antenna coupling, EMIT works hand-in-hand with Ansys HFSS to combine RF device interference analysis with best-in-class electromagnetic simulation. As a result, a complete solution for reliably predicting RFI effects in multi-antenna environments with multiple transmitters and receivers has been developed.

All significant RF interactions, including non-linear device component effects, are computed by EMIT's powerful analysis engine. In a laboratory environment, diagnosing RFI in complex environments is notoriously challenging and costly, but using EMIT's dynamic related results views, the root-cause of any interference can be quickly identified using graphical signal trace-back and diagnostic summaries that display the precise origin and direction that interfering signals take to each receiver. If the source of the interference is identified, EMIT allows for a quick assessment of different RFI mitigation options in order to find the best solution. The new HFSS/EMIT Datalink makes it possible to construct an RFI analysis model in EMIT directly from the physical 3-D model of the mounted antennas in HFSS. This allows for a smooth end-to-end workflow for a full RFI solution in RF environments ranging from large platform cosite interference to electronic device receiver desense.

3.3.3 Installed Antenna and RF Cosite Analysis:

Engineers may use advanced unit cell simulation in Ansys HFSS to model infinite and finite phased-array antennas with all electromagnetic effects, such as mutual coupling, array lattice definition, finite array edge effects, dummy components, and element blanking.

Under any beam scan situation, a candidate array design may analyze the input impedances of all components. Based on element match (passive or driven) far-field and near-field pattern behavior over any scan condition of interest, phased array antennas may be optimized for performance at the element, subarray, or complete array stage. One or more antenna elements are mounted inside a unit cell in infinite array modeling. To create an infinite number of elements, the cell includes periodic boundary conditions on the surrounding walls to mirror fields. The method is particularly useful for predicting array-blind scan angles, which may occur when array beam steering is used. This technology enables full array analysis, which includes the prediction of all mutual coupling, scan impedance, element patterns, array patterns, and array edge effects.

3.3.4 Signal and Power Integrity Analysis:

SI Circuits, when combined with HFSS, can be used to analyze signal integrity, power integrity, and EMI issues in PCBs, electronic packages, connectors, and other complex electronic interconnects caused by shrinking timing and noise margins.

From die-to-die across ICs, bundles, connectors, and PCBs, HFSS with SI Circuits can handle the complexities of modern interconnect design. Engineers can understand the performance of high-speed electronic products long before constructing a prototype in hardware by leveraging the HFSS advanced electromagnetic field simulation capability, which is dynamically connected to efficient circuit and device simulation.

CHAPTER-4

Antenna Design

4.1. Introduction

Steps to design the antenna using HFSS:

1. Launch the HFSS application of any version available.

2. In the HFSS application, from the menu bar, click “File” option and click “New”.

3. From the menu bar, click “Project” menu and click “Insert HFSS Design”.

4. Click on “Modeler” option and under the “Units” option select the units as “mm” i.e., Millimeters.

5. Click on the “Draw” option from menu bar and select “Rectangle” option. Place the rectangle pointer on the Cartesian plane and draw a rectangle.

6. Once you draw the rectangle, go to “CreateRectangle” window and enter the dimensions of the rectangle as per requirement.

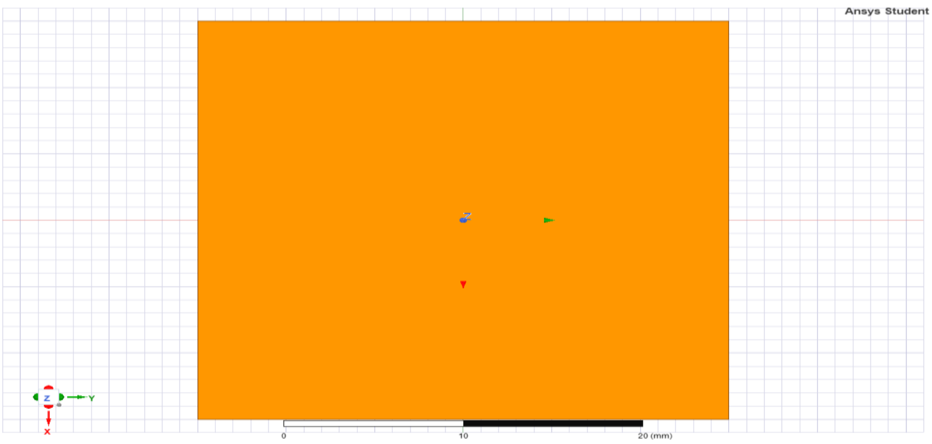


Figure 4.1.1 Ground Structure in HFSS.

7. In order to provide the rectangular slot on the ground structure, draw the rectangle on the ground according to the dimensions of the slot.

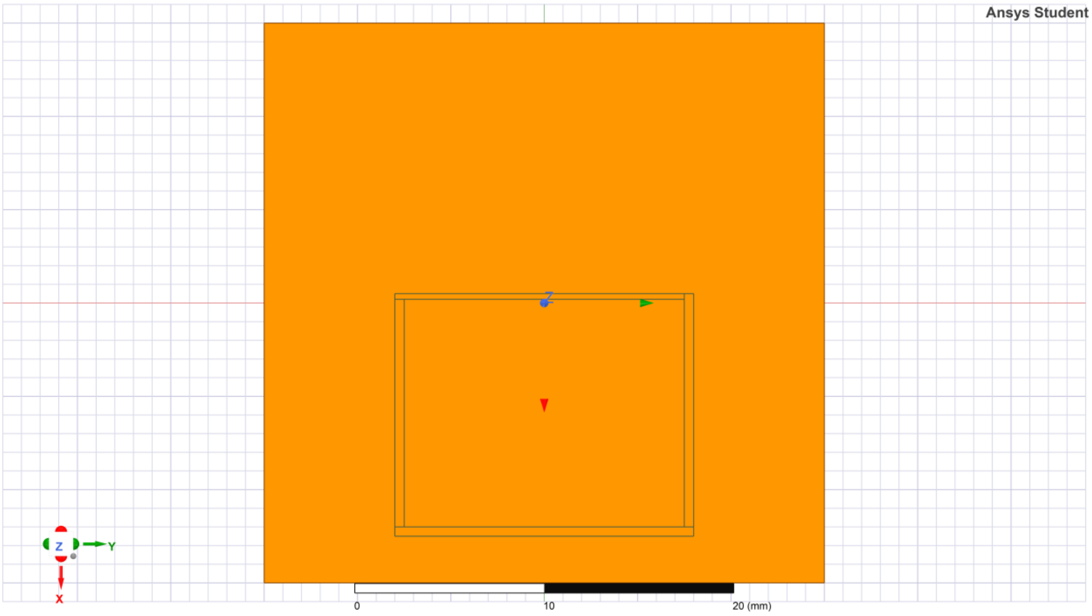


Figure. 4.1.2. Ground with rectangle slots before cut.

8. Select the four rectangles that are placed on the ground structure and use the “Subtract” option available in the HFSS to provide the cuts on the antenna.

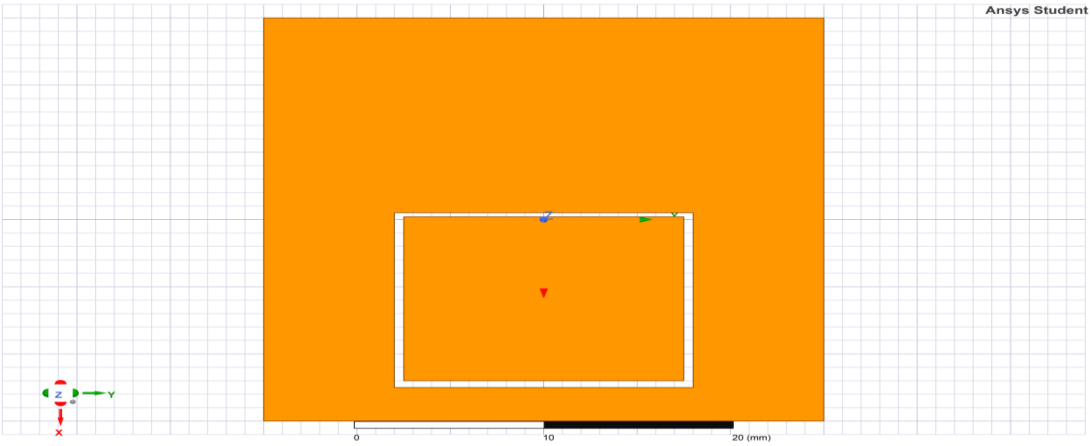


Figure. 4.1.3. Ground with rectangle slots after cut.

9. Select the "Ground" structure and under the options, click on "Assign Boundary" and select "Perfect E".
10. Now for laying the substrate on the ground, select "Box" option from the "Draw" menu bar and draw the box structure with the same dimensions.

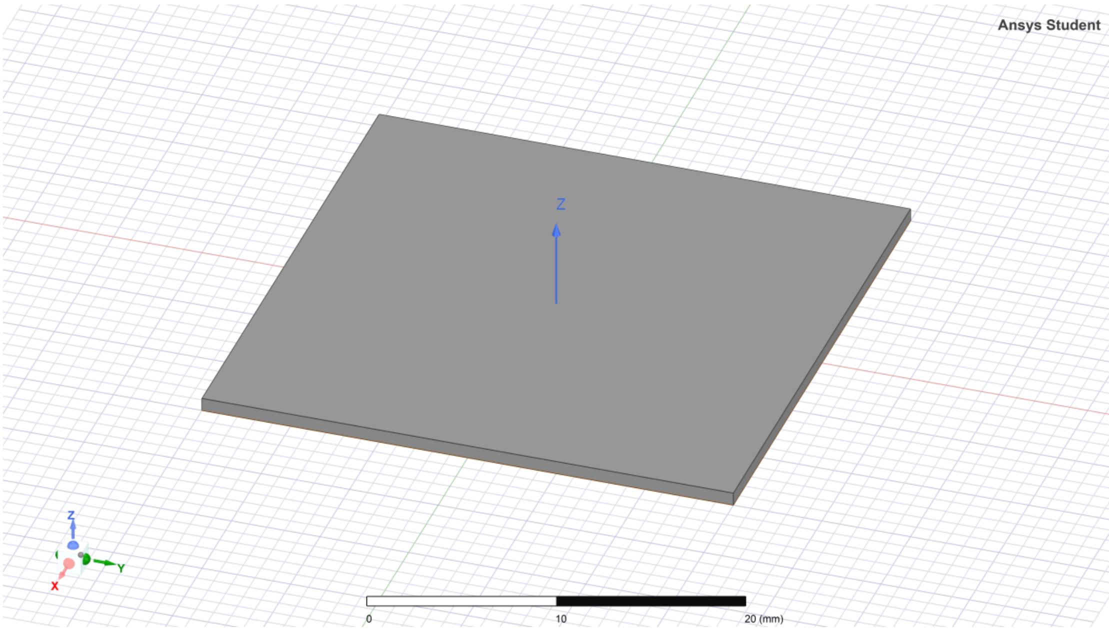


Figure. 4.1.4. Substrate in HFSS.

11. Assign the required substrate material to the substrate structure.
12. Draw a rectangle patch on top of the substrate for the required dimensions.

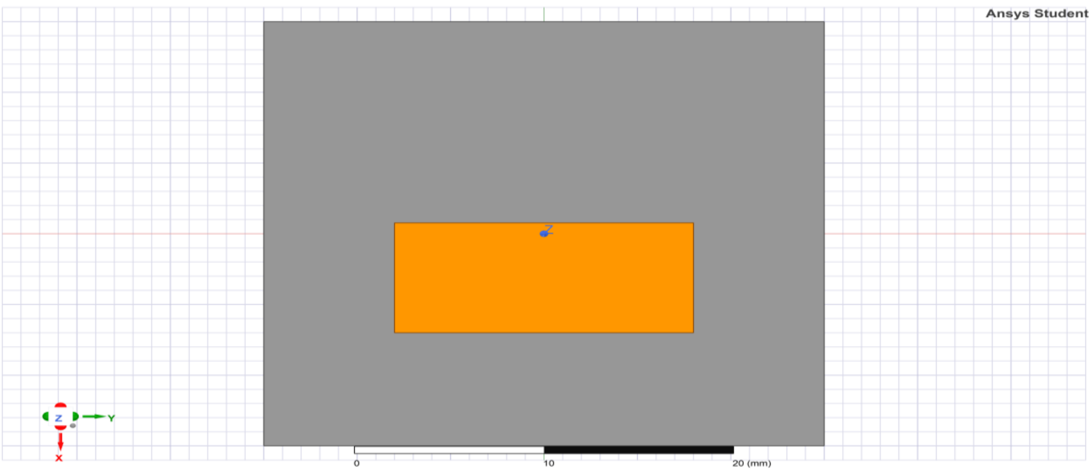


Figure. 4.1.5. Patch in HFSS.

13. Draw another rectangle for Strip line at the bottom of the patch from the edge of the substrate.

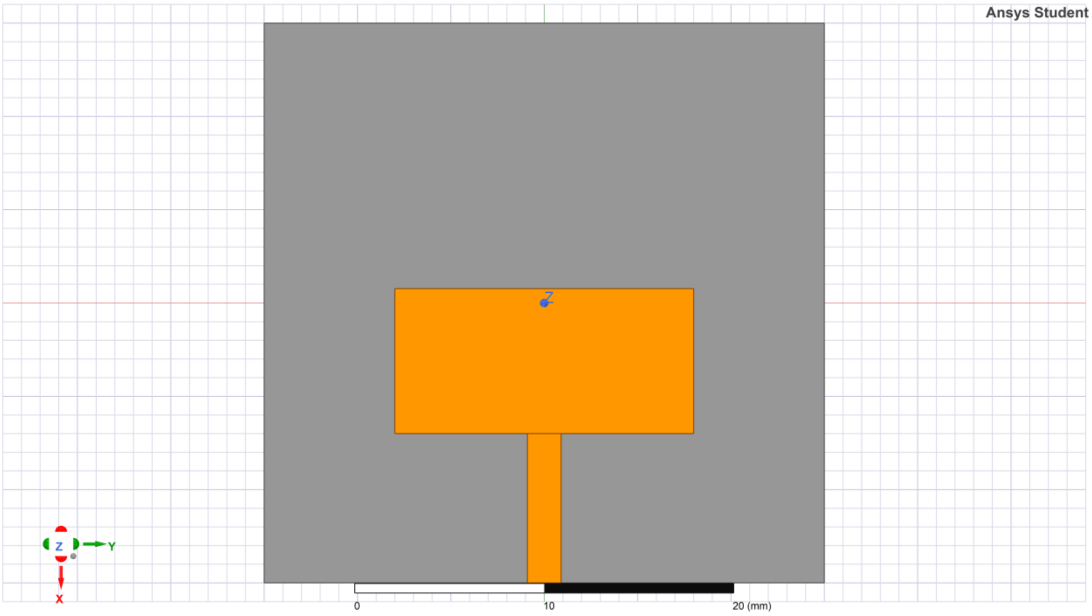


Figure. 4.1.6. Strip line with patch in HFSS.

14. Select the "Patch" rectangle and "Strip line" rectangle to unite the both rectangle for Monopole structure.

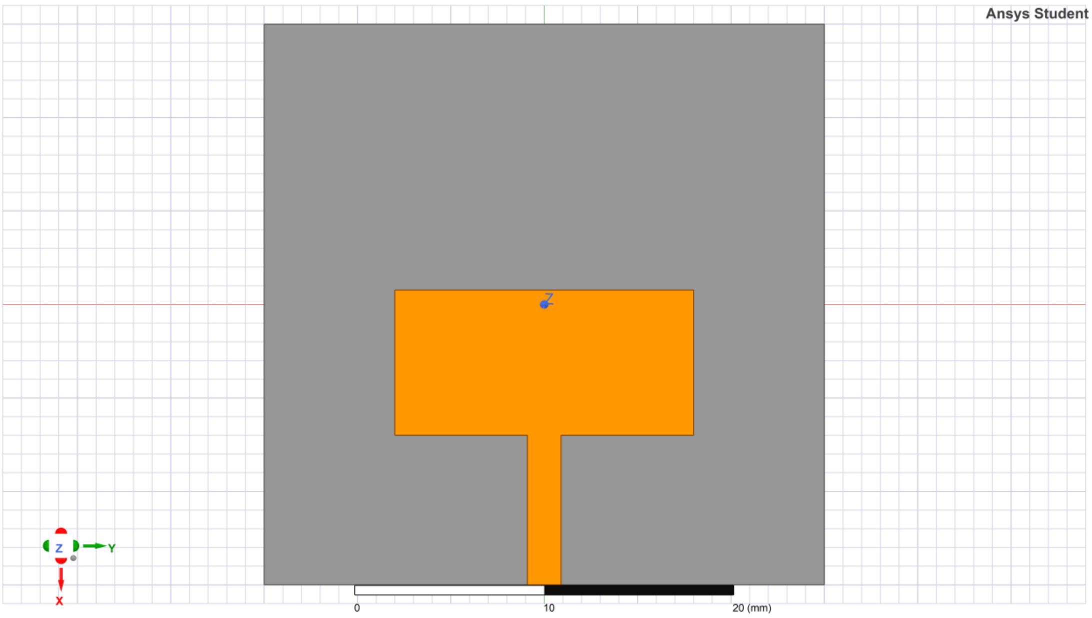


Figure. 4.1.7. Strip line united with patch in HFSS.

15. To truncate the edges of the rectangular patch into a triangular patch, use the “Polyline” option.

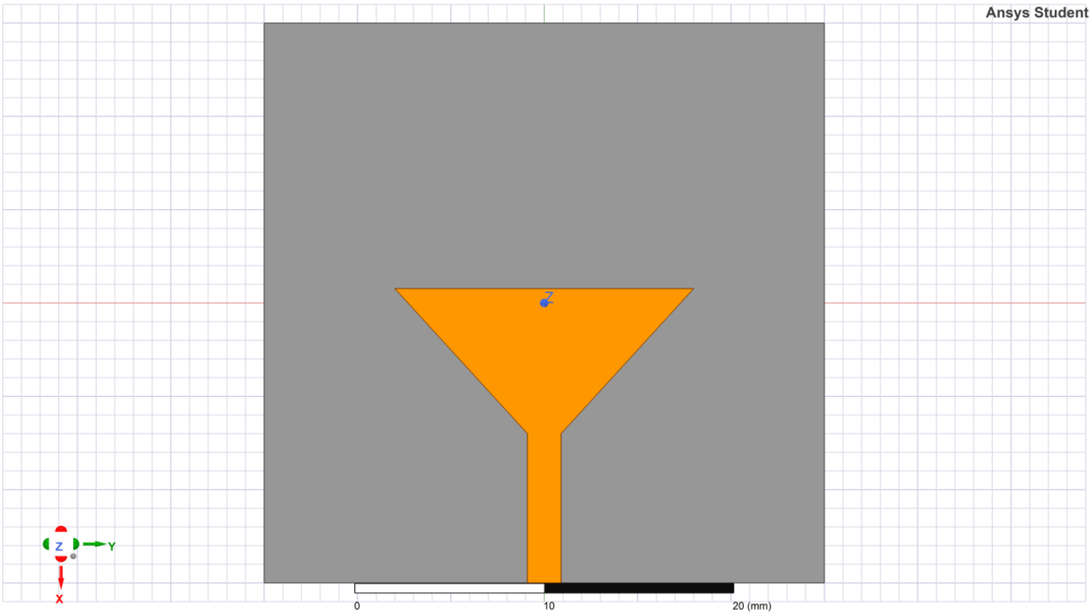


Figure. 4.1.8. Patch after truncating edges.

16. To add slots on the patch, draw two rectangles on the patch and subtract those rectangles from the patch.

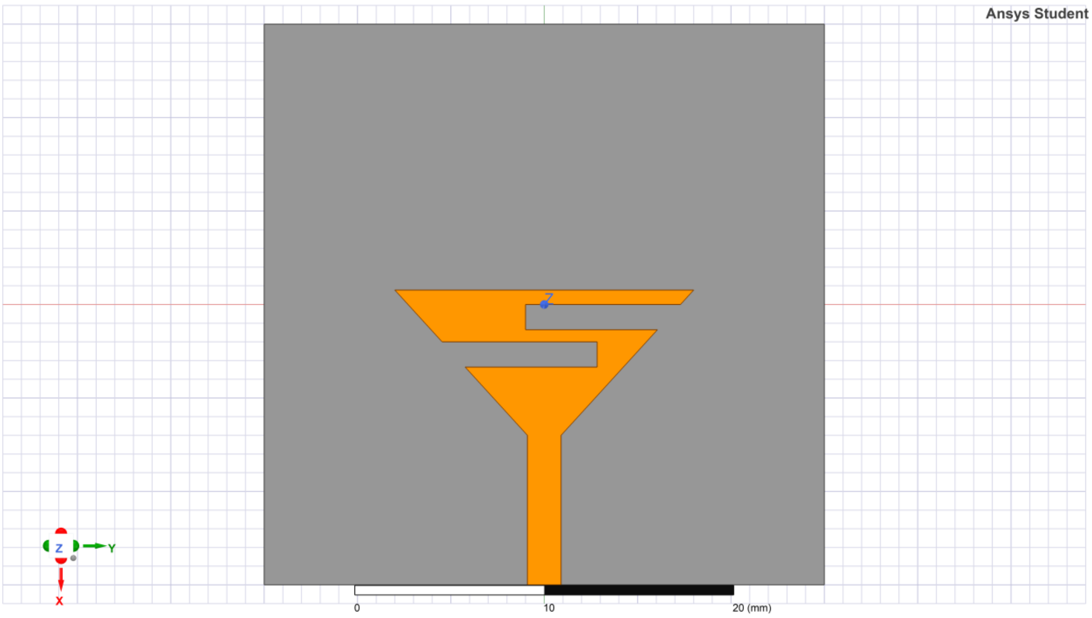


Figure. 4.1.9. Patch with the cuts.

17. Add two rectangles as stubs for the extension of the patch.

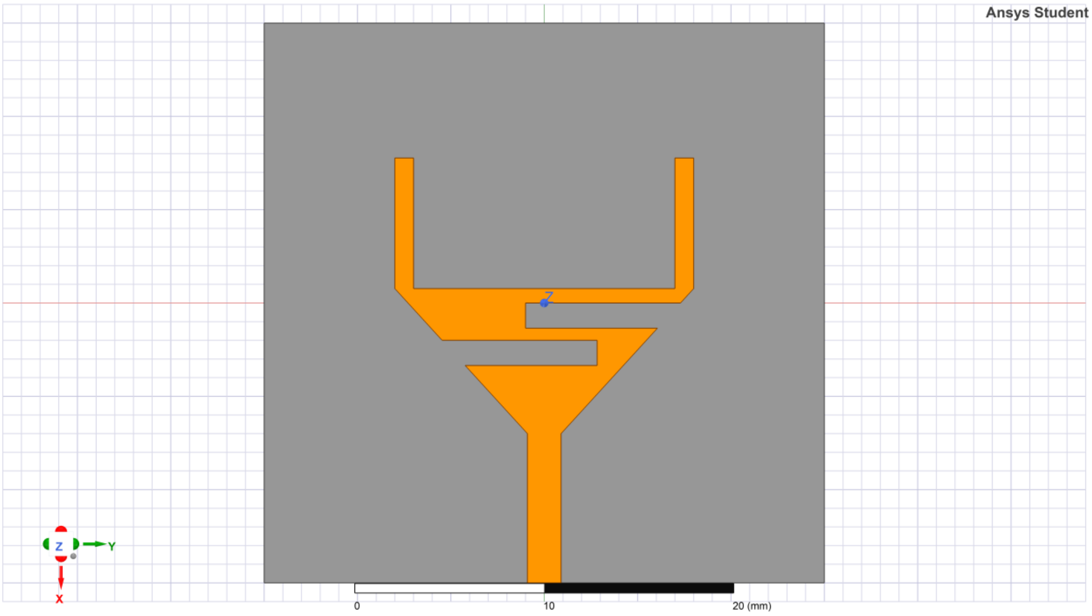


Figure. 4.1.10. Patch with stubs in HFSS.

18. Select Patch structure and "Assign boundary" as "Perfect E".

19. Now, to provide feed to the antenna, a Port must be created. Here, we use lumped port as the port type. Draw a rectangle on the face of the substrate box that is between the Patch plane and Ground plane.

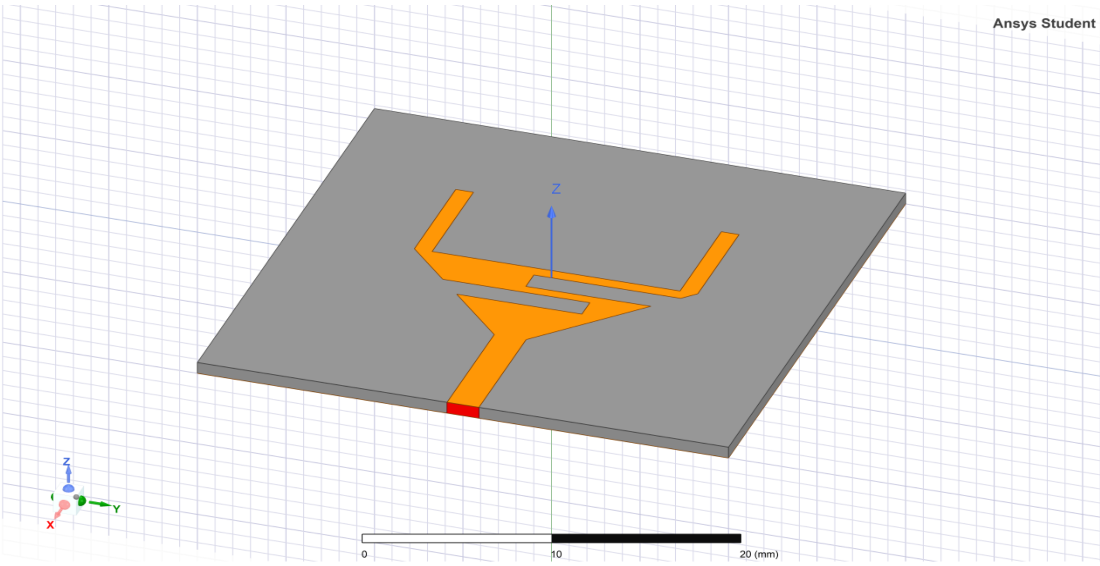


Figure. 4.1.11. Port to the patch in HFSS.

20. Select the port and under the options, click “Assign Excitation” and select “Lumped Port” under the “Port” option.

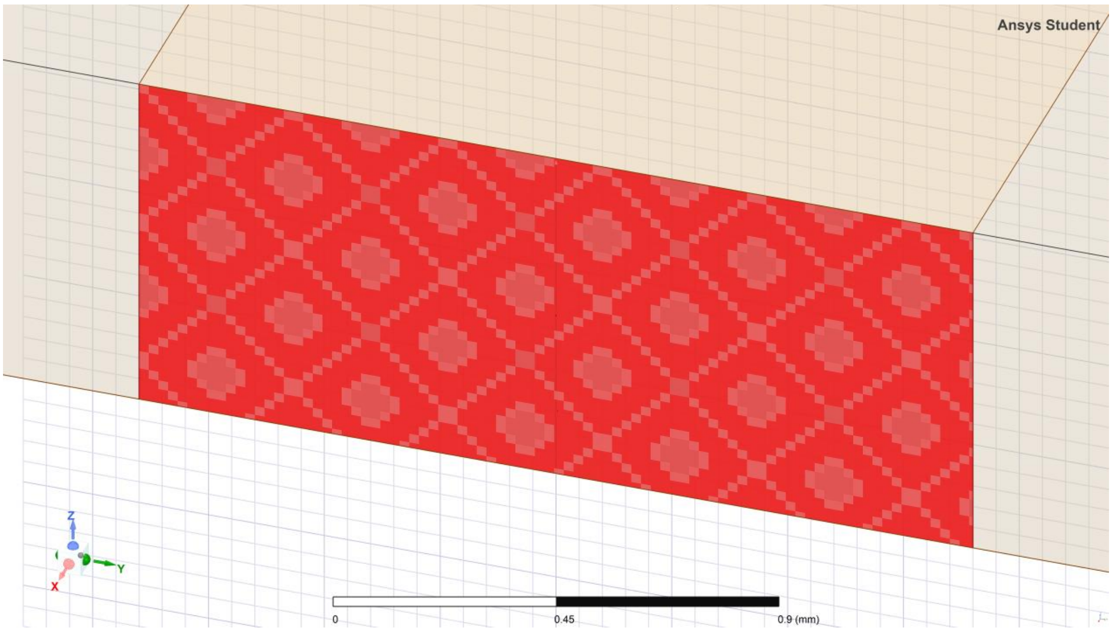


Figure. 4.1.12. Port with excitation in HFSS.

21. To put two diodes in the rectangular slot on the ground, two rectangles must be drawn. The distance between the diodes and the size of diodes should be observed according to requirement.

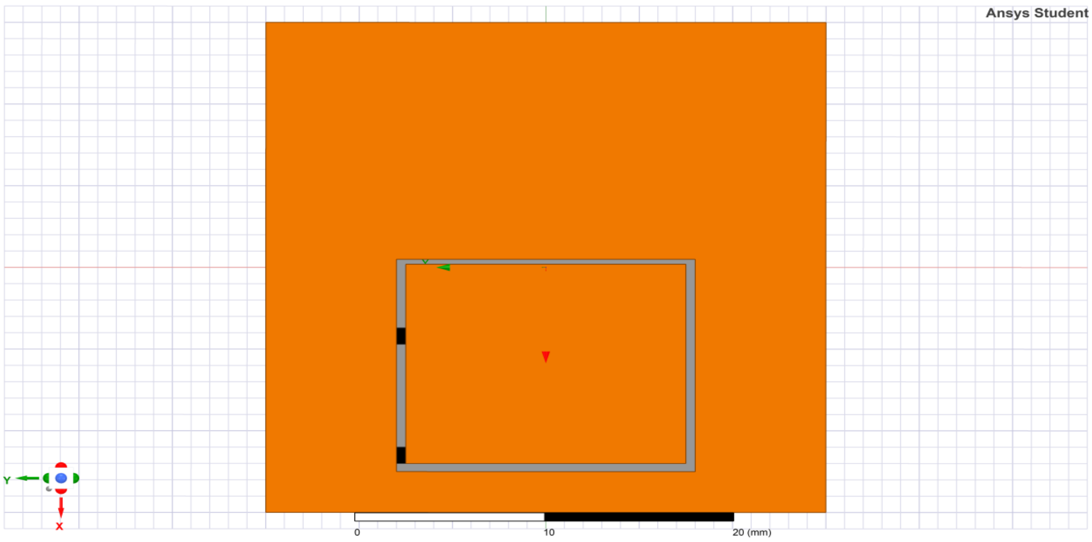


Figure. 4.1.13. Ground with diode structures in HFSS.

22. Now, select a diode and assign the required electrical parameters using "Lumped RLC" option under the "Assign boundary" option in the options window. Repeat the same with the other diode.

23. Draw a box, such that the antenna is at the centre of the box and enter the dimensions of the box. This box acts as the "Air box" or "Radiation Box".

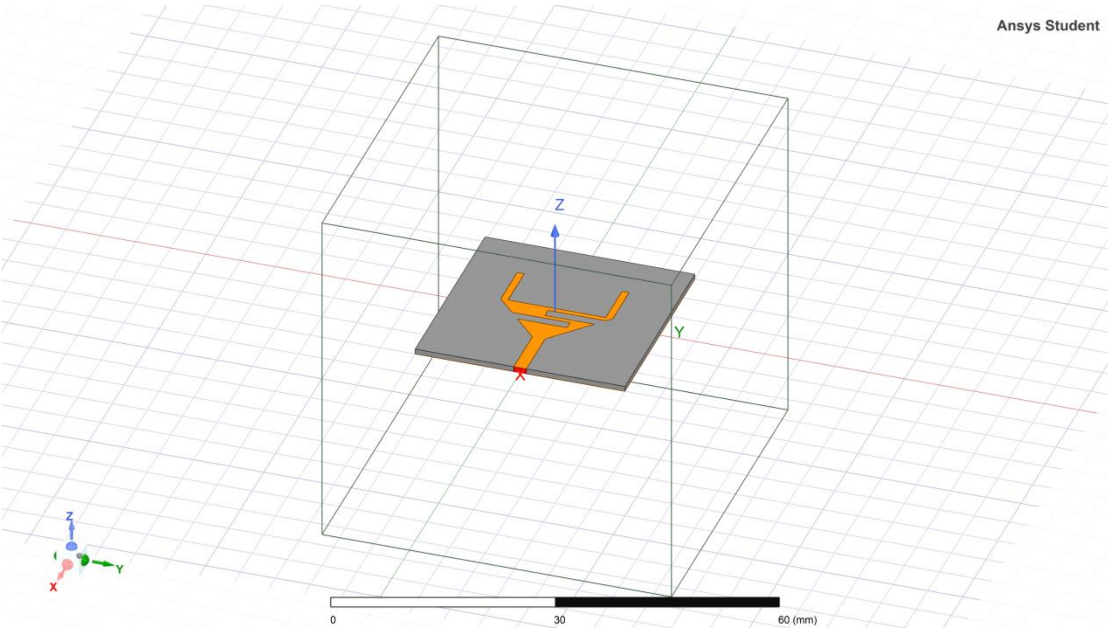


Figure. 4.1.14. Air box of the antenna in HFSS.

24. Select the airbox box and assign material as "air". Select the box again and assign the boundary as "Radiation".

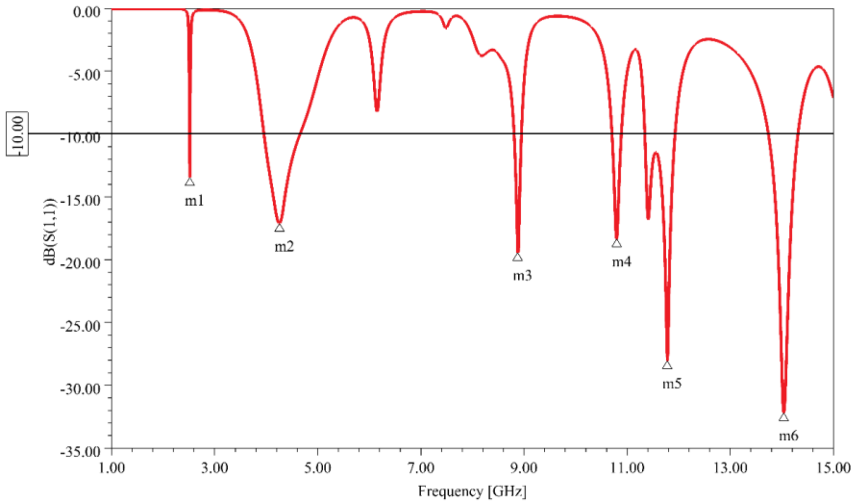
25. The design of the antenna is completed.

5. RESULTS

As the proposed antenna design contains two p-i-n diodes, the antenna can be operated in four different modes by switching these diodes ON/OFF. In each mode, various characteristics and parametric quantities such as S-parameter, Surface Current distribution, Gain and Radiation pattern are measured to assess the performance of the proposed antenna.

5.1 Mode 1 (Both Diodes OFF)

5.1.1 Return Loss plot

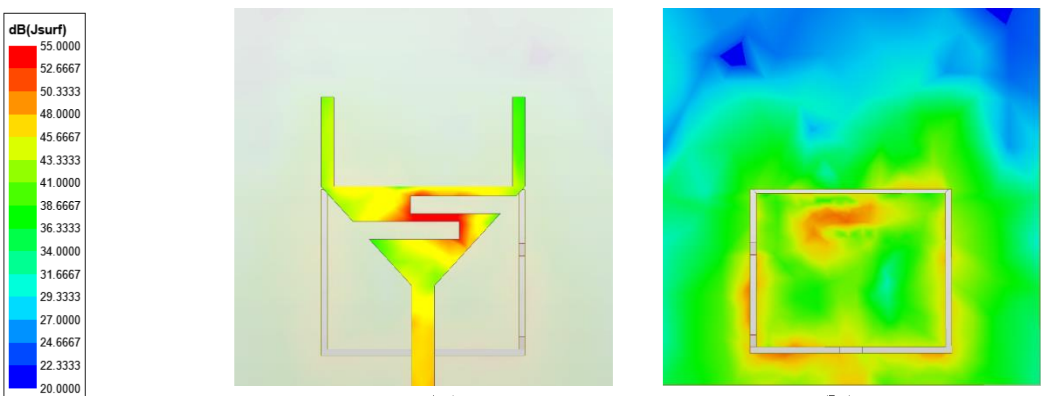


Name	Freq	Y
m1	2.5200	-14.4012
m2	4.2700	-16.8269
m3	8.8800	-19.4407
m4	10.8000	-18.3517
m5	11.7800	-28.0479
m6	14.0400	-32.1917

Figure 5.1 S_{11}-Parameter Plot in mode 1

Figure 5.1 shows the return loss of the proposed antenna when both the diodes are in OFF state. It shows that the antenna operates in multi-bands and the return loss is less than -10dB at the resonant frequencies 2.52 GHz, 4.27 GHz, 8.88 GHz, 10.80 GHz, 11.78 GHz, 14.04 GHz. This covers S, C, X, Ku – bands.

5.1.2 Surface current Distribution



(a) (b)

Figure 5.2 Surface Current Distribution, (a) top view and (b) bottom view

Figure 5.2 shows the surface current distribution of the proposed antenna in top and bottom view in mode 1.

5.1.3 Gain plot

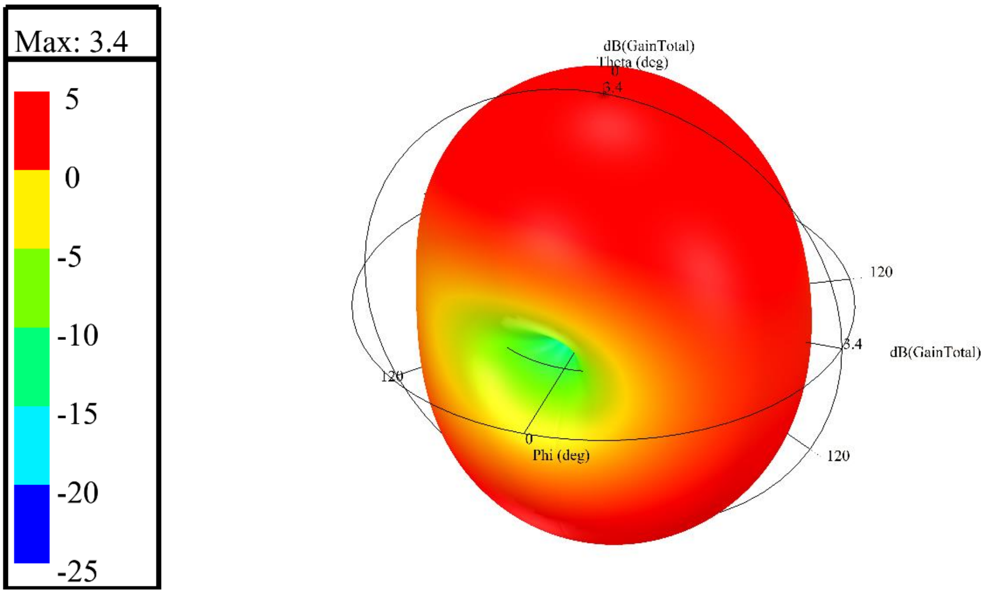


Figure 5.3 Gain Plot

Figure 5.3 shows the 3d polar gain plot of the antenna, when both the diodes are in OFF state. Here at Ø = 0^0, a maximum gain of 3.4 dB is observed.

5.1.4 Radiation Plot

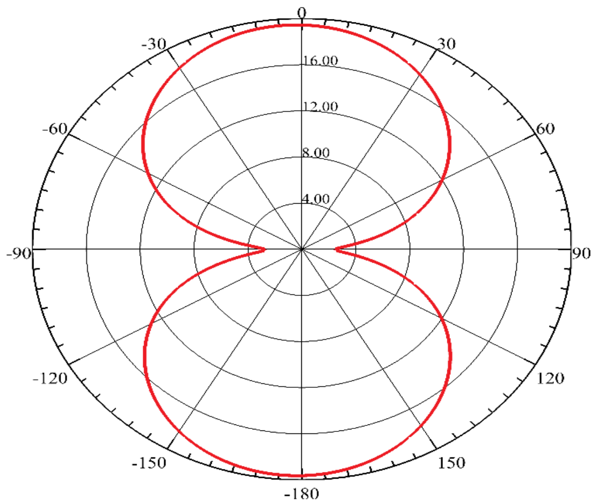
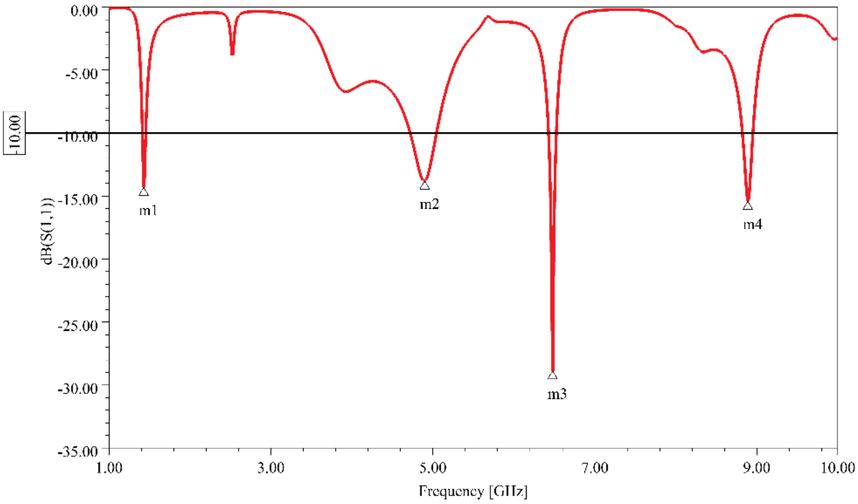


Figure 5.4 Radiation Plot

The above figure 5.4 shows the radiation plot of the proposed antenna in mode 1. And the radiation pattern is omni-directional.

4.2 Mode 2 (D_1 OFF, D_2 ON)

4.2.1 Return Loss plot

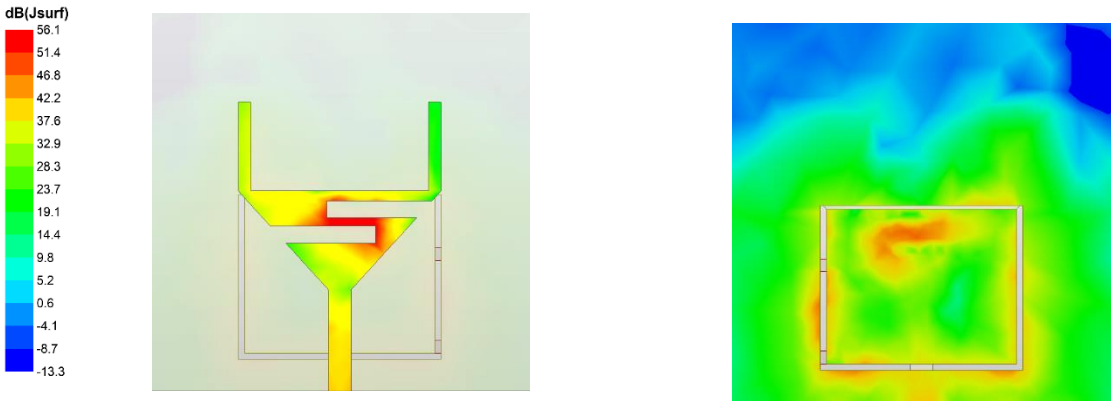


Name	Freq	Y
m1	1.4300	-14.3263
m2	4.8900	-13.8137
m3	6.4800	-28.8855
m4	8.8900	-15.4324

Figure 5.5 S_{11}-Parameter Plot

Figure 5.5 shows the return loss of the proposed antenna when D_1 OFF, D_2 ON. It shows that the antenna operates in multi-bands and the return loss is less than -10dB at the resonant frequencies 1.43 GHz, 4.89 GHz, 6.48 GHz, 8.89 GHz. This covers L, C, X, Ku – bands.

5.2.2 Surface current Distribution



(a) (b)

Figure 5.6 Surface Current Distribution, (a) top, (b) bottom view

Figure 5.6 shows the surface current distribution of the proposed antenna in top and bottom view when D_1 OFF, D_2 ON.

5.2.3 Gain plot

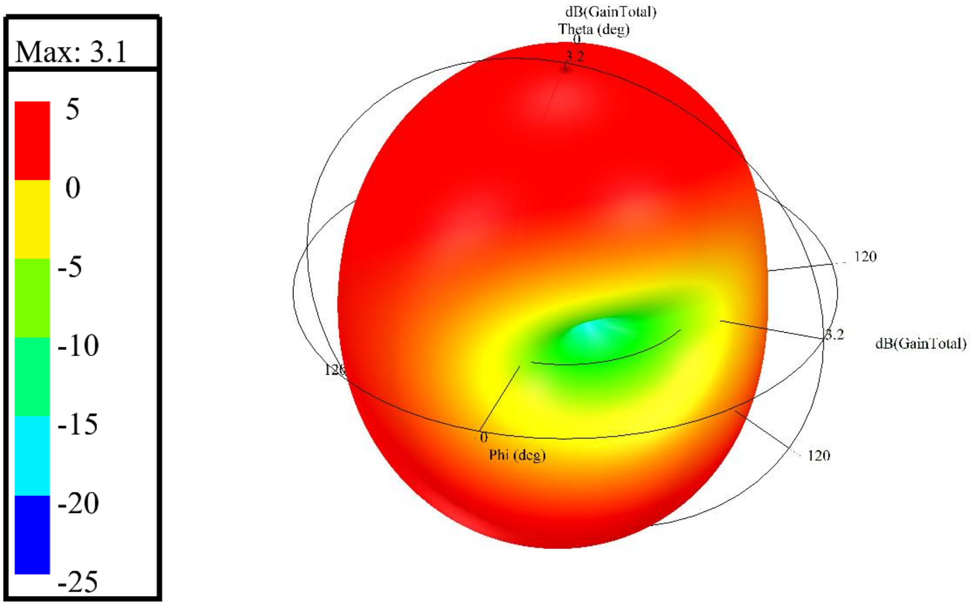


Figure 5.7 Gain Plot

Figure 5.7 shows the 3d polar gain plot of the antenna, when D_1 OFF, D_2 ON. Here at $Ø = 0^0$, a maximum gain of 3.1 dB is observed.

5.2.4 Radiation Plot

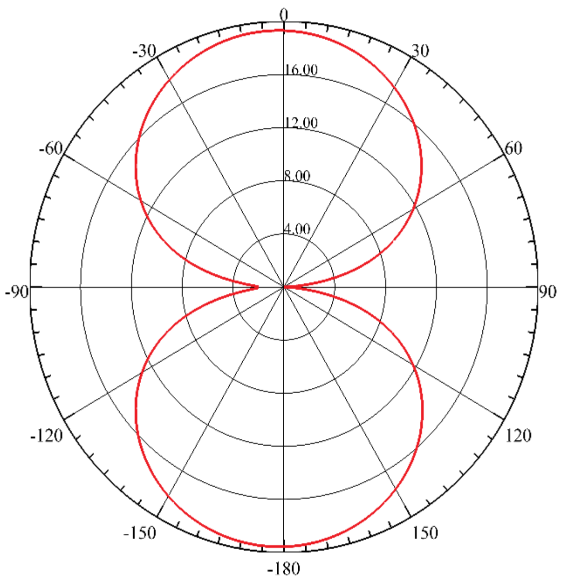
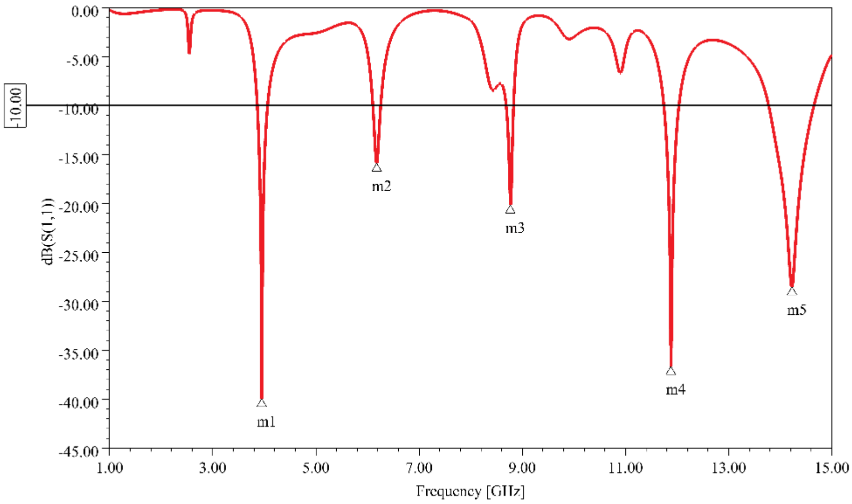


Figure 5.8 Radiation Plot

The above figure 5.8 shows the radiation plot of the proposed antenna in mode 2. And the radiation pattern is omni-directional.

5.3 Mode 3 (D_1 ON, D_2 OFF)

5.3.1 Return Loss plot

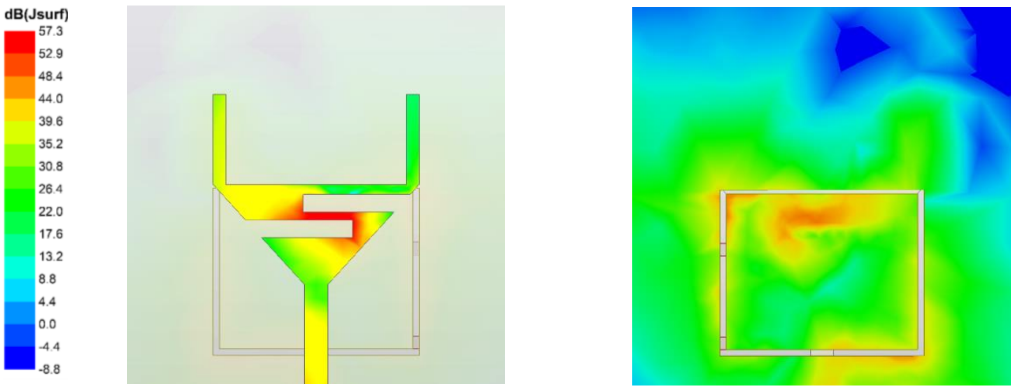


Name	Freq	Y
m1	3.9500	-39.9545
m2	6.1800	-15.8985
m3	8.7700	-20.1557
m4	11.8800	-36.6563
m5	14.2300	-28.5320

Figure 5.9 S_{11}-Parameter Plot

Figure 5.9 shows the return loss of the proposed antenna when D_1 ON, D_2 OFF. It shows that the antenna operates in multi-bands and the return loss is less than -10dB at the resonant frequencies at 3.95 GHz,6.18 GHz,8.77 GHz,11.88 GHz,14.23 GHz. This covers S, C, X, Ku – bands.

5.3.2 Surface current Distribution



(a) (b)

Figure 5.10 Surface Current Distribution, (a) top, (b) bottom view

Figure 5.10 shows the surface current distribution of the proposed antenna in top and bottom view when D_1 ON, D_2 OFF.

5.3.3 Gain plot

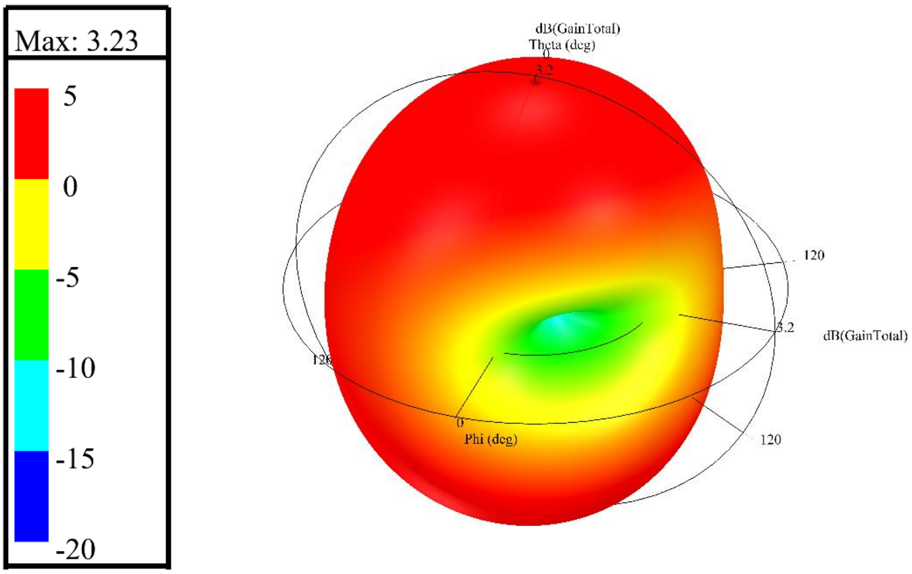


Figure 5.11 Gain Plot

Figure 5.11 shows the 3d polar gain plot of the antenna, when D_1 ON, D_2 OFF. Here at Ø = 0^0, a maximum gain of 3.23 dB is observed.

5.3.4 Radiation Plot

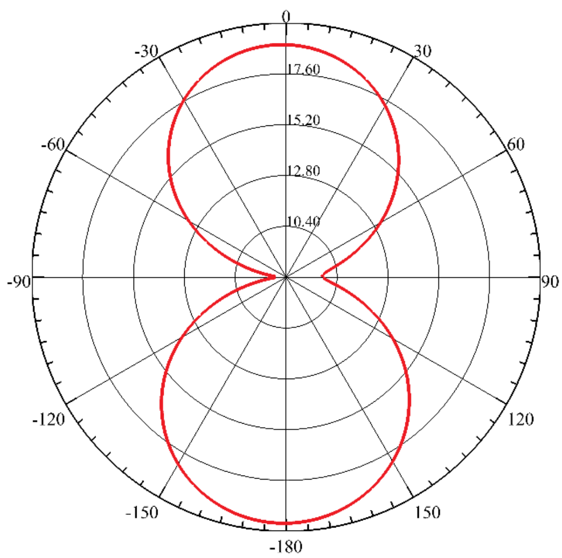
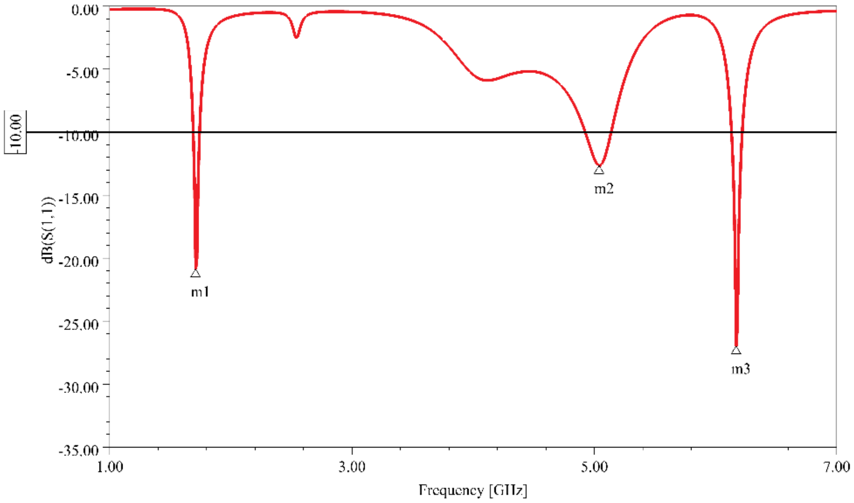


Figure 5.12 Radiation Plot

The above figure 5.12 shows the radiation plot of the proposed antenna in mode 3. And the radiation pattern is omni-directional.

5.4 Mode 3 (D_1 ON, D_2 ON)

5.4.1 Return Loss plot

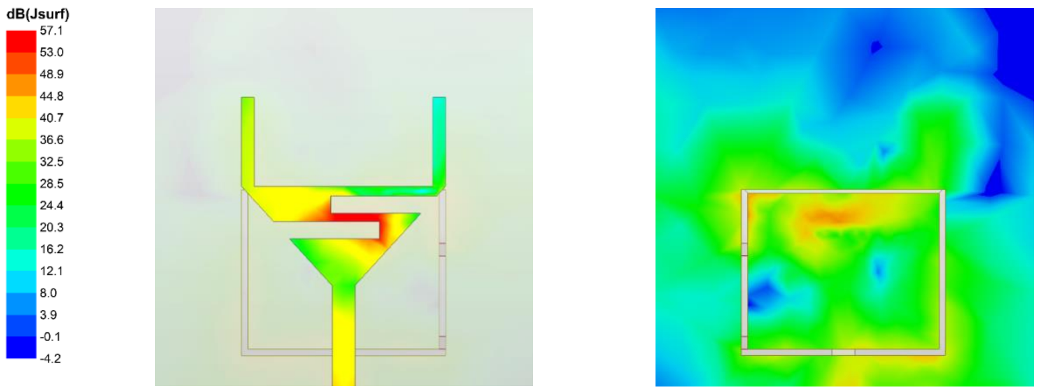


Name	Freq	Y
m1	1.7100	-20.8730
m2	5.0400	-12.6576
m3	6.1700	-26.9871

Figure 5.13 S_{11}-Parameter Plot

Figure 5.13 shows the return loss of the proposed antenna when D_1 ON, D_2 ON. It shows that the antenna operates in multi-bands and the return loss is less than -10dB at the resonant frequencies at 1.71 GHz,5.04 GHz,6.17 GHz. This covers L, C– bands.

5.4.2 Surface current Distribution



(a) (b)

Figure 5.14 Surface Current Distribution, (a) top, (b) bottom view

Figure 5.14 shows the surface current distribution of the proposed antenna in top and bottom view when D_1 ON, D_2 ON.

5.4.3 Gain plot

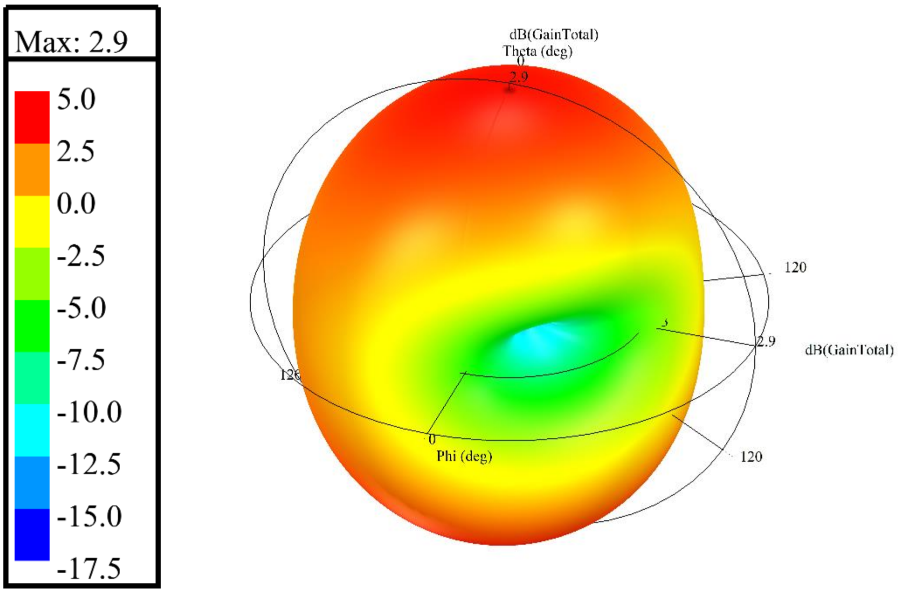


Figure 5.1 Gain Plot

Figure 5.15 shows the 3d polar gain plot of the antenna, when D_1 ON, D_2 ON. Here at $Ø = 0^0$, a maximum gain of 2.9 dB is observed.

5.4.4 Radiation Plot

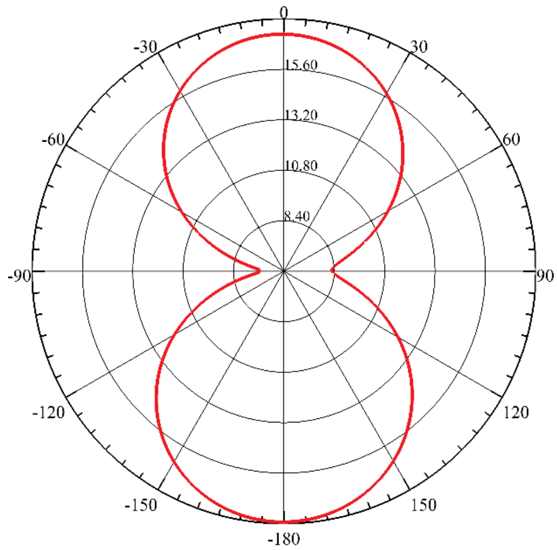


Figure 5.16 Radiation Plot

The above figure 5.16 shows the radiation plot of the proposed antenna in mode 4. And the radiation pattern is omni-directional.

CONCLUSION

In this paper, a multiband frequency reconfigurable antenna for wireless applications such as WLAN, WiFi, LTE etc is designed. The proposed antenna can operate in multiple bands namely L, S, C, X, Ku – bands by adjusting the switching state of the two p-i-n diodes and even in each state without any modifications in patch. The designed antenna has the potential to be employed in multi-mode and wireless communication systems due to its simple design and compact size (30×30×0.762 mm^3) and it's good S-parameter values, gain, radiation properties for multiple operating bands. When both the diodes are OFF, the antenna offers multi-band operations at 2.52 GHz (S-band), 4.27 GHz (C-band), 8.88 GHz, 10.80 GHz, 11.78 GHz (X-band), 14.04 GHz (Ku-band). Similarly antenna resonates at 1.43 GHz (L-band), 4.89 GHz, 6.48 GHz (C-band), 8.89 GHz (X-band), 13.71 GHz (Ku-band) when D_1 OFF, D_2 ON case. Meanwhile for D_1 ON, D_2 OFF case at 3.95 GHz (S-band), 6.18 GHz (C-band), 8.77 GHz, 11.88GHz(X-band), 14.23 GHz(Ku-band). Whereas when both the diodes are ON, antenna resonates at 1.71 GHz(L-band), 5.04 GHz, 6.17 GHz(C-band).The proposed antenna can also be used in Bluetooth and ZigBee applications.

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Paper Publications Details

[1] **Deepa Bammidi, Venkatesh Sabbisetti, Reshma Gude, Govardhan Lingampalli, Vinay Kumar Bodepu** “DESIGN OF MULTIBAND FREQUENCY RECONFIGURABLE ANTENNA FOR WIRELESS APPLICATIONS”. 7th International Conference on Micro-Electronics, Electromagnetics and Telecommunications. **ICMEET** - 2022 22-23 July, 2022.