

DESIGN AND FABRICATION OF RF ENERGY HARVESTING ANTENNA

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Electronics and Communication Engineering

by

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **ULISHETTY NAGA SUBRAMANYAM (39130487), SYAMALA YASHWANTH REDDY (39130539)** who carried out the project entitled "**DESIGN AND FABRICATION OF RF ENERGY HARVESTING ANTENNA**" under our supervision from November 2022 to April 2023.

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ABSTRACT

This paper describes the antenna design for RF power harvesting system. The design goes through three phases designing of antenna, matching network and rectifier. A dual band Microstrip antenna suspended above ground plane is designed to operate in GSM 1.8 and ISM 2.4 GHz bands. The antenna incorporates the capacitive feed strip which is fed by coaxial probe technique where the inductive impedance of probe is effectively cancelled by the capacitive patch. The designed antenna provides good frequency response and fairly directional radiation pattern. This paper describes the antenna design for RF power harvesting system. The basic objective of this research is to develop a receiving antenna for energy harvesting to charge passive device. The design goes through three phases designing of antenna, matching network and rectifier. To develop the proposed antenna on a different substrate. To simulate the design in HFSS software

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LIST OF ABBRIVIATIONS

WLAN	Wireless Local Area Network
FIT	Finite Integration Technique
HFSS	High Frequency Structure Simulator
PCB	Printed Circuit Board
EMF	Electro Magnetic Field
HPC	High Performance Computing

CHAPTER 1

INTRODUCTION

Over past two decades, wireless systems have been developed and implemented to such an extent that frequency spectrum has become dense. These systems are Wi-Fi, cellular radio, radio broadcast and TV broadcast. Large amount of ambient energy (e.g., wind, solar and tide) is widely available and large-scale technologies are being developed efficiently to capture it. Also, there are small amounts of “wasted” energy that could prove to be useful if captured. Recovering even a fraction of this energy would have a significant environmental and economic impact. This is where energy harvesting (EH) comes in. The concept of energy harvesting is not new rather it came into picture 100 years back [1]. The method of extracting energy from environment to generate electricity is called energy harvesting or energy scavenging. This technology offers two main advantages a) Energy is freely available b) It is "green" for the environment. The ambient energy present around us can be harvested using a rectifying antenna, popularly known as rectenna [14]. RECTENNA is a rectifying antenna that is used to convert electromagnetic energy into direct current electricity. In recent years, alternate energy sources has become essential as the demand for power increases. In the last energy decades energy obtained from external sources such as thermal energy, solar power, wind energy, and RF energy has been in use for various purposes. To provide unlimited energy for the lifespan of electronic devices, energy harvesting uses inexhaustible sources with no adverse environmental effect.

1.1 OVERVIEW

This paper focuses on RF energy harvesting. The receiving antenna captures the RF energy from surrounding sources, such as nearby mobile phones, wireless LANs (WLANs), FM/AM radio signals, broadcast television signals and rectified

into a usable DC voltage. One possibility to overcome their power limitations is to extract (harvest) energy from the environment to either recharge a battery, or even to directly power the electronic device. To meet various objectives in last few years, several antenna designs of rectenna have been proposed for use in RF energy harvesting. Among the other antennas, microstrip patch antennas are widely used because of their low profile, light weight, and planar structure. This paper presents several methods to design and energy harvesting device depending on the type of energy available and also presents microstrip path structural rectenna are explains RF signal harvester for powering low consumption electrical devices. harvest high-frequency energy in free space and convert it to DC power. Harvesting RF energy and converting it into useful DC power requires careful design: - An efficient antenna is designed to boost RF signal. - A matching circuit to transfer maximum RF power from source to load. - Rectifying circuit to convert input RF to DC.

1.2 ANTENNA



Fig.1.2 Antenna

In radio engineering, an antenna or aerial is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver. In transmission, a radio transmitter supplies an 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 a radio wave in order to produce an electric current at its terminals, that is applied to a receiver to be amplified. Antennas are essential components of all radio equipment.

An antenna is an array of conductors (elements), electrically connected to the receiver or transmitter. Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional, or high-gain, or "beam" antennas). An antenna may include components not connected to the transmitter, parabolic reflectors, horns, or parasitic elements, which serve to direct the radio waves into a beam or other desired radiation pattern. Antennas are required by any radio receiver or transmitter to couple its electrical connection to the electromagnetic field.^[8] Radio waves are electromagnetic waves which carry signals through the air (or through space) at the speed of light with almost no transmission loss. An automobile's whip antenna, a common example of an omnidirectional antenna. Antennas can be classified as omnidirectional, radiating energy approximately equally in all directions, or directional, where energy radiates more along one direction than others. (Antennas are reciprocal, so the same effect occurs for reception of radio waves.) A completely uniform omnidirectional antenna is not physically possible. Some antenna types have a uniform radiation pattern in the horizontal plane, but send little energy upward or downward. A "directional" antenna usually is intended to maximize its coupling to the electromagnetic field in the direction of the other station

1.3 ANTENNA PARAMETERS

An antenna is an electrical conductor or system of conductors
Transmitter - Radiates electromagnetic energy into space
Receiver - Collects electromagnetic energy from space

1.4 POWER GAIN

Power gain (or simply **gain**) is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. Consider the power density radiated by an isotropic antenna with input power P_0 at a distance R which is given by $S = P_0/4\pi R^2$. An isotropic antenna radiates equally in all directions, and its radiated power density S is found by dividing the radiated power by the area of the sphere $4\pi R^2$. An isotropic radiator is considered to be 100% efficient and also measure that combines an antenna's efficiency Σ antenna and directivity D

$$G = \Sigma_{\text{antenna}} \cdot D$$

1.4.1 EFFICIENCY

The **efficiency** Σ antenna of an antenna is the total radiated power P_0 divided by the input power at the feedpoint

$$\Sigma_{\text{antenna}} = P_0/P_{\text{in}}$$

A transmitting antenna is supplied power by a feedline, a transmission line connecting the antenna to a radio transmitter. The **input power** P_{in} to the antenna is typically defined to be the power supplied to the antenna's terminals (the *feedpoint*), so antenna power losses do not include power lost due to joule heating in the feedline and reflections back down the feedline due to antenna/line impedance mismatches.

The electromagnetic reciprocity theorem guarantees that the electrical properties of an antenna, such as efficiency, directivity, and gain, are the same when the antenna is used for receiving as when it is transmitting.

1.4.2 DIRECTIVITY

An antenna's directivity is determined by its radiation pattern, how the radiated power is distributed with direction in three dimensions. All antennas are directional to a greater or lesser extent, meaning that they radiate more power in some directions than others.

The direction is specified here in spherical coordinates (θ, ϕ) where θ is the altitude or angle above a specified reference plane (such as the ground), while ϕ is the **azimuth** as the angle between the projection of the given direction onto the reference plane and a specified reference direction (such as north or east) in that plane with specified sign (either clockwise or counterclockwise).

The distribution of output power as a function of the possible directions (θ, ϕ) is given by its radiation intensity $U(\theta, \phi)$ (in SI units: watts per steradian, $\text{W}\cdot\text{sr}^{-1}$). The output power is obtained from the radiation intensity by integrating the latter over all solid angles $d\Omega = \sin\theta d\theta d\phi$

PATH LOSS

Path loss normally includes *propagation losses* caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever-increasing sphere), *absorption losses* (sometimes called penetration losses), when the signal passes through media not transparent to electromagnetic waves, *diffraction losses* when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena.

$$PL = P_t / P_r$$

RETURN LOSS

Return loss is an important parameter when testing an antenna. It is related to impedance matching and the maximum transfer of power theory. It is also a measure of the effectiveness of an antenna to deliver of power from source to antenna. The return loss (RL) is defined by the ratio of the incident power of the antenna (P_{in}) to the power reflected back from the antenna of the source (P_{ref}) the mathematical expression is

$$R = 10 \log_{10}(P_i / P_r)$$

CHAPTER 2

LITERATURE SURVEY

2.1 Microstrip antenna designs for RF energy harvesting

In recent years, alternate energy sources have become essential as the demand for power increases. In the last energy decades energy obtained from external sources such as thermal energy, solar power, wind energy, and RF energy has been in use for various purposes. To provide unlimited energy for the lifespan of electronic devices, energy harvesting uses inexhaustible sources with no adverse environmental effect. This paper focuses on RF energy harvesting. The receiving antenna captures the RF energy from surrounding sources, such as nearby mobile phones, wireless LANs (WLANs), FM/AM radio signals, broadcast television signals and rectified into a usable DC voltage. One possibility to overcome their power limitations is to extract (harvest) energy from the environment to either recharge a battery, or even to directly power the electronic device. To meet various objectives in last few years, several antenna designs of rectenna have been proposed for use in RF energy harvesting. Among the other antennas, microstrip patch antennas are widely used because of their low profile, light weight, and planar structure. This paper presents several methods to design and energy harvesting device depending on the type of energy available and also presents microstrip path structural rectenna are explains RF signal harvester for powering low consumption electrical devices.

Flexible printed monopole antennas for WLAN applications

Khaleel, Haider R., Hussain M. Al-Rizzo, Daniel G. Rucker, and Yahiea Al-Naiemy

In this paper, we present two thin/flexible printed monopole antennas for Wireless Local Area Network (WLAN) applications. The first design is a single band antenna which operates at 2.4 GHz while the second one is a dual band antenna operates at 2.5 GHz

and 5.2 GHz. The dimensions of the proposed antennas are: (26.5 mm × 25) and (35 mm × 25) mm for the single band and dual band respectively. Antenna properties, such as gain, far-field radiation patterns, coupling coefficient, expressed in terms of the scattering parameter S11 are provided. Design and simulations are performed using CST Microwave Studio software which is based on the Finite Integration Technique (FIT). Moreover, the effect of folding the antenna was performed experimentally on both designs to study its influence on the antenna performance. The achieved gain for the single band antenna is 1.8 dB with a measured bandwidth of 270 MHz. The dual band antenna achieved a gain of 1.8 dB and 4 dB at 2.5 GHz and 5.2 GHz respectively, and measured bandwidths of 305 MHz and 480 MHz at the first and second band respectively. The proposed thin and flexible designs along with antennas characteristics are suitable for integration into flexible technologies for WLAN applications.

"Design and Analysis of Dual-Band Circular Patch Antenna for X-Band Applications with Enhanced Bandwidth"

Pradeep, Pendli, and S. K. Satyanarayana

An antenna is a crucial component in the wireless communication system which converts electrical waves to EM waves and vice-versa which leads to revaluation in wireless communication technology. Due to this reason the experiment was performed on a simple circular patch antenna for better radiation along with wide transmission bandwidth. In this paper, a simple circular microstrip antenna structure is designed to operate at dual bands. The proposed antenna consists of a circular radiating patch, a 50-ohm feedline line, a quarter-wave impedance matching transmission line, and a ground plane. It meets significant requirements for large bandwidth, optimized gain, minimum reflections, and small size with high directivity and efficiency. This antenna contains FR4 Epoxy substrate material with permittivity 4.4 and size 36mm x 36mm x 1.67mm. ANSOFT HFSS simulator is used to analyze various parameters like return loss, VSWR, Impedance, and gain. The Resonant Frequency of the designed antenna is 8.77 GHz and 10.6 GHz. with minimum Return Loss of -52 dB and -21.66 dB respectively. It was also observed that 1.005 and 1.2 VSWR at 8.77 GHz and 10.6 GHz respectively

Flexible Patch Antenna using Different Substrates for WBAN Applications.

Prabhakar, D., M. Akhil Poorvika, M. Venkata Krishna Sai, and M. Subba Naidu

This paper introduces a flexible patch antenna using different substrates. The flexible antennas are becoming popular in the present-day era and these antennas play key role in Bio-Medical applications. The paper deals with the primary approach in using Polyester, Rubber which are the materials used as the substrates for patch antenna. The mechanical properties of these substrates make antenna flexible. The antenna operates in the ISM band (2.4-2.5) GHz. The ISM band is suitable for flexible operation. The antenna with measured substrate properties was simulated in High Frequency Structure Simulator (HFSS). Approximate values in resonant frequency may be due to finite ground plane dimensions and variation of feed location. The simulated results suggest that flexible substrate antenna can be successfully used for Medical Applications

A reconfigurable triple-notch-band antenna integrated with defected microstrip structure band-stop filter for ultra-wideband cognitive radio applications

Yasir I. A. Al-Yasir ¹ , Mohammed K. Alkhafaji ² , Hana'a A. Alhamadani ²

The proposed UWB CRA can work at eight modes by controlling switches ON and OFF. Moreover, impedance bandwidth, design procedures, and radiation patterns are presented for analysis and explanation of this antenna. The designed antenna operates over the frequency band between 3.1 GHz and 14 GHz (bandwidth of 127.5%), with three notched bands from 4.2 GHz to 6.2 GHz (38.5%), 6.6 GHz to 7.0 GHz (6%), and 12.2 GHz to 14 GHz (13.7%).

CHAPTER 3

METHODOLOGY

3.1 EXISTING SYSTEM

The basic objective of this research is to develop a receiving antenna for energy harvesting to charge passive devices. After designing and simulating proposed micro strip antenna, next thing is to implement this microstrip antenna on hardware. This paper describes the antenna design for RF power harvesting system. The design goes through three phases designing of antenna, matching network and rectifier. A dual band Microstrip antenna suspended above ground plane is designed to operate in GSM 1.8 and ISM 2.4 GHz bands.

The antenna incorporates the capacitive feed strip which is fed by coaxial probe technique where the inductive impedance of probe is effectively cancelled by the capacitive patch. The designed antenna provides good frequency response and fairly directional radiation pattern

3.2 PROPOSED SYSTEM

Designing and fabricating an RF energy harvesting antenna requires careful consideration of various factors, such as the frequency range of interest, the power requirements, the size and form factor, and the efficiency of the antenna. Here's a proposed system for designing and fabricating an RF energy harvesting antenna:

Define the requirements The first step is to define the requirements of the RF energy harvesting antenna. This includes the frequency range of interest, the power requirements, the size and form factor, and any other specific requirements. Conduct research to understand the existing state-of-the-art technology, current trends, and best practices for designing and fabricating RF energy harvesting antennas.

Antenna design Use a software tool, such as ANSYS HFSS or CST Microwave Studio, to design the antenna. The design should be optimized for the frequency range of interest, and the geometry should be adjusted to maximize the antenna's efficiency.

Simulation Perform electromagnetic simulation to verify the antenna's performance. Use simulation tools, such as ANSYS HFSS or CST Microwave Studio, to analyze the antenna's performance metrics, such as return loss, radiation pattern, and gain.

Prototype fabrication Once the design is finalized, fabricate a prototype of the antenna. Use a suitable manufacturing process, such as 3D printing, photolithography, or CNC machining.

Characterization Characterize the performance of the prototype antenna using a network analyzer, spectrum analyzer, or other relevant measurement equipment. Measure key performance parameters, such as input impedance, bandwidth, and radiation efficiency.

Optimization Based on the results of the characterization, optimize the antenna design and fabrication process to improve performance.

Scaling up If the prototype antenna meets the requirements, scale up the production to fabricate more antennas.

Testing and validation Test and validate the performance of the fabricated antennas to ensure that they meet the specifications.

Documentation Document the design, fabrication, and testing process to ensure repeatability and scalability.

3.3 OBJECTIVE

- This paper describes the antenna design for RF power harvesting system
- The basic objective of this research is to develop a receiving antenna for energy harvesting to charge passive devices

- The design goes through three phases designing of antenna, matching network and rectifier.
- To develop the proposed antenna on a different substrate. To simulate the design in HFSS software

BLOCK DIAGRAM

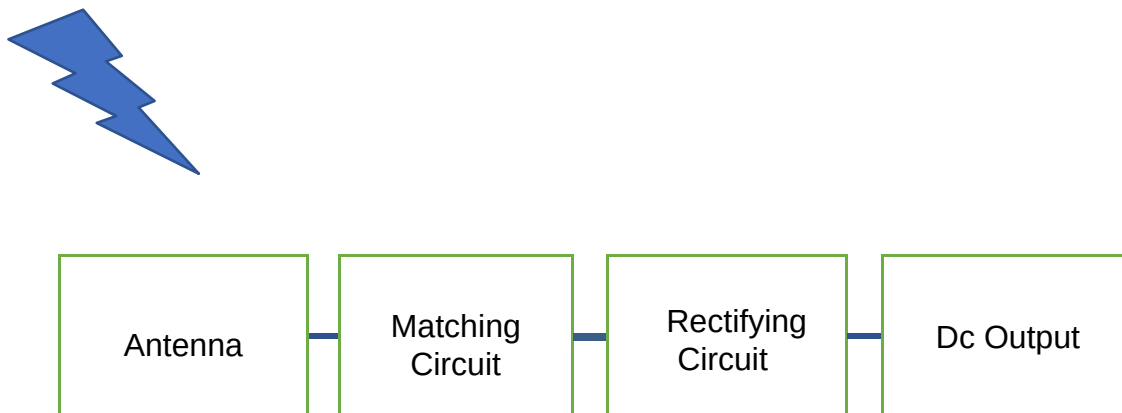


Fig.3.3 Block Diagram

CHAPTER 4

REQUIRMENT ANALYSIS

Only software only requirement are the specifications of project that helps in the work done of the project.

4.1 SOFTWARE REQUIREMENTS

Ansys hfss 15.0 (64 bit)

4.2 ADVANTAGES

- Ease of manufacturing.
- High Gain.
- The simulated results suggest that flexible substrate antenna can be successfully used for Medical Applications

4.3 ANTENNA DESIGN MODEL

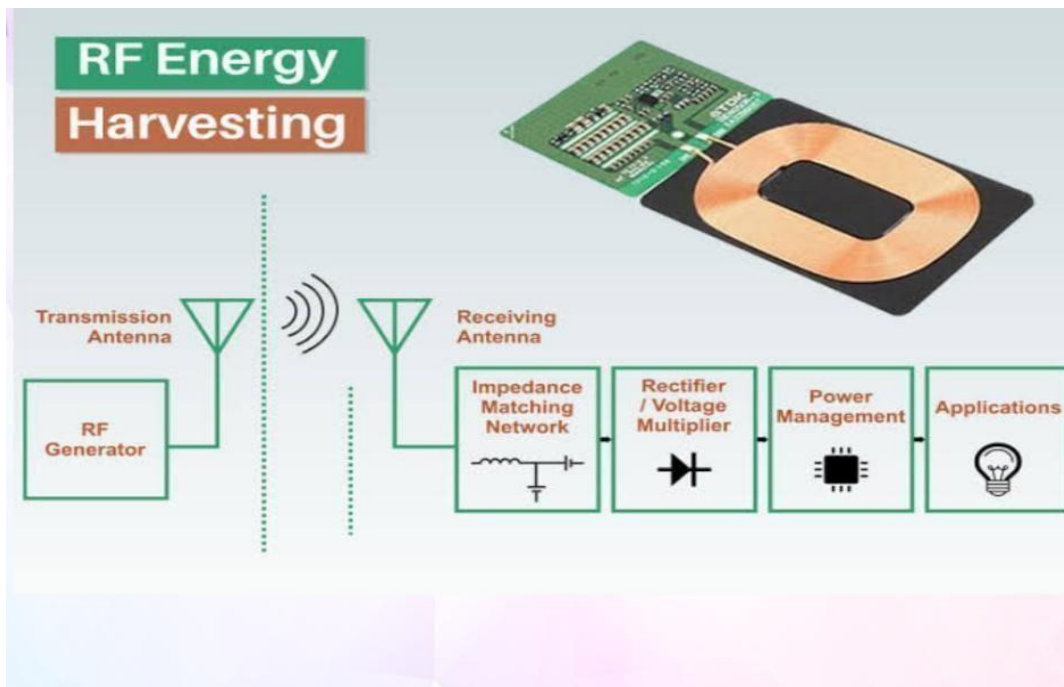


Fig.4.3 Antenna design model

4.4 LIBRARIES

Motivation for wireless energy harvesting

An early definition of a wireless power transmission system portrays a unit that emits electrical power from one place and captures it at another place in the Earth's atmosphere without the use of wires or any other supporting medium. The history of RF power scavenging in free space originated in the late 1950s with a microwave-powered helicopter system. Later, the concept of power harvesting or energy scavenging was explained as a technique for reaping energy from the external environment using different methods including thermoelectric conversion, vibrational excitation, solar energy conversion, and pressure gradients. This technique promises tremendous scope for the replacement of small batteries in low power electrical devices and systems. Figure 1 introduces the structure of an RF energy harvesting system and factors that contribute to the performance of the whole system. RF wireless power harvesting (WPH) holds vast potential for replacing batteries or increasing their lifespans. Currently, batteries power a majority of low-power remote sensor devices and embedded equipment. In fact, batteries have finite lifespans and require periodic replacements. By applying power harvesting technologies, devices and equipment can become self-sustaining with respect to the energy required for operation, thereby obtaining an unlimited operating lifespan. Thus, the demand for power maintenance will become negligible. The sources for WPH are available in many forms, such as solar power, wind energy, thermal energy, electromagnetic energy, kinetic energy, etc. Among them, electromagnetic energy is abundant in space and can be retrieved without limit. Electromagnetic waves come from a variety of sources such as satellite stations, wireless internet, radio stations, and digital multimedia broadcasting. A radio frequency power harvesting system can capture and convert electromagnetic energy into a usable direct current (DC) voltage. The key units of an RF power harvesting system are the antenna and rectifier circuit that allows the RF power or alternating current (AC) to be converted into DC energy.

The processing of battery wastes is a critical problem. A majority of batteries end up in landfills, leading to the pollution of the land and water underneath. The most effective solution for reducing battery wastes is to avoid using them. Applying WPH technology will help to reduce the dependency on batteries, which will ultimately have a positive impact on the environment. Moreover, the process of harnessing electromagnetic energy will not generate wastes as it is a clean energy source. A summary of the present sources of energy available for power harvesting is shown in Table 1. The data in Table 1 was collected from references . In comparison with thermal or kinetic energy, electromagnetic energy is not limited by space or time. The RF wave is available both indoors and outdoors, in rural and urban areas, throughout the day. Despite its low power density in the environment, an intentional source can be added for more efficient power transmission and a boosting circuit can be built to suit the requirements of the load application. This feature promotes research to realize RF WPH technology through applications such as wireless sensor networks (WSNs) and Internet of Things (IoT)

4.5 FUNDAMENTALS OF RF TRANSMISSION

Understanding electromagnetic waves is important to design an RF WPH system. The behavior of electromagnetic waves varies according to the distance, frequency, and conducting environment. Depending on the requirements of the application, the designer needs to select suitable parameters for electromagnetic waves to obtain best results. The loss of power in space can be characterized by free space path loss (FSPL), which is the loss of signal power during propagation in free space. Calculating FSPL requires information about the antenna gain, frequency of transmitting wave, and distance between the transmitter and receiver. The behavior of electromagnetic waves depends upon the distance from the transmitting antenna. These characteristics are categorized into two segments: far-field and near-field. While the electromagnetic wave pattern at the far-field is relatively uniform, in the near-field, the electric and magnetic components are very strong and independent such that one component can dominate the other. The near-field region is considered as the space that lies within the Fraunhofer's distance and the far-field region lies outside the Fraunhofer's distance. The distribution of the near and far field regions is

illustrated in Fig. 2. The Fraunhofer's distance is defined as where d_f is the Fraunhofer's distance, D is the maximum dimension of the radiator (or diameter of the antenna), and λ is the wavelength of the electromagnetic wave. Although the Fraunhofer creates a boundary region, the actual transition between regions is not distinct. Inside the near-field, the space from the antenna to a distance of $3 D^2 / \lambda$ is a non-radiative/reactive near-field region, where E and H fields are not in phase, creating energy distortion. As we propagate forward in this region towards the far-field, we encounter a radiative near-field or Fresnel region, where the reactive behavior of electromagnetic waves is not dominant but the phases of E and H fields still vary with distance. For a transmitter–receiver antenna in the far-field free space, the power propagation at the receiver antenna can be expressed as where P_R is power at the receiver antenna; G_R is receiver antenna gain relative to the isotropic source (dBi); λ is the wavelength of the electromagnetic signal, which is equal to the speed of light in vacuum divided by the signal frequency, $\lambda = c / f$; and $k = 2\pi/\lambda$ is the wave number. From the above formula, the FSPL, PL for far-field can be inferred as $d (1) f = 2D^2$, $P_R = (2) P_T G_T G_R / (4\pi R)^2$, or in case f is measured in MHz, distance R is measured in km, and gain G_T and G_R are measured in dBi, the above function becomes by using the path loss equation, it is possible to indicate the signal power at the far field region. However, this equation does not present all the factors that affect the propagation process such as reflection, diffraction, absorption, etc. In contrast to the uniform far-field wave, the electric and magnetic fields behave unusually in the near-field. The relationship between electric and magnetic waves in the near-field varies unpredictably with time and space and is too complicated to predict. All these factors make estimating the power density at this range problematic. The FSPL estimation process is critical to design the energy-harvesting unit. Being informed about the amount of power that the system is required to handle helps the designer in choosing the right technology and method. Since the electromagnetic field (EMF) is widely used for a variety of purposes, there must be a standard to ensure the safe operation of EMF devices. For this purpose, the International Electrotechnical Commission [21] established international standards and frequency limits for EMFs. For safety measures, there must be a separate

emission and immunity standard for each class of application including broadcast, communication, military, medical, and household appliances. On the other hand, radiation exposure must be considered carefully, especially in biomedical applications. EMFs at different spectrums affect the human body differently. Between 1 MHz to 10 GHz frequency, EMF possibly penetrates through tissues and produce heat because of energy absorption. EMFs over 10 GHz are strongly blocked by the skin, and then the heat created causes damage such as eye cataracts or skin burns if the field density is above 1000 W/m². Hoping to prevent negative health effects when utilizing EMF applications, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) developed general guidelines for EMF exposure limits recognized under the World.

Health Organization (WHO). To date, there have been no consistent reports corroborating that lasting exposure to EMF shortens one's life span or induces adverse health conditions. However, for safety issues, RF emission power and frequency must be considered carefully to avoid unwanted damages.

Wireless power harvesting evaluation metrics: There are various parameters that need to be evaluated, which decide the performance of a WPH design. Evaluation merits change depending on different applications. Nevertheless, critical values such as efficiency, sensitivity, operation distance, output power are defined as standards to make comparisons. However, tradeoffs exist between these values such as operation distance and overall efficiency. Moreover, besides this merit, other manufacturing auxiliary factors like low cost, maturity of fabrication process, and bulk manufacturing availability are also paramount.

Operation range: Operation distance is mostly related to operation frequency. In fact, transmission at high frequencies is attenuated by atmospheric conditions more than at low frequencies while low frequency penetrates deeper through matter. Therefore, if the application of WPH is for implantable devices, then the transmitting frequency should not exceed the megahertz range.

RF-DC power conversion efficiency (PCE): This is the ratio between the amount of power applied to the load and that retrieved by the antenna. Generally, the RF-DC

PCE covers the efficiency of the rectifier, voltage multiplier, and storage elements. PCE can be simply calculated as the ratio of power delivered to the load to the retrieved power. RF transmission loss in space is not considered in this term. where P_{load} is power delivered to the load and retrieved is harvested power at the antenna. Factors that determine the value of PCE include parasitic effects, leakage in the circuits, design topologies, and nonlinear thresholds of electrical components.

Resonator Q factor: The Q factor is generally defined as a dimensionless value that describes how strong the resonance is and the bandwidth of resonance [22]. In electric circuits, the Q factor represents how much the peak voltage increases when the system resonates at resonant frequency. From this η PCE = (6) P_{load} Retrieved , concept, the equation of Q factor can be express as the formula below [23]: From the equation above, it is inferred that a high Q factor comes with a narrow resonant bandwidth, but high voltage gain is obtained at resonance. Further, this equation also indicates that the Q factor is inversely proportional to the energy dissipated per cycle. The specific Q factor for capacitor C and inductor L at frequency ω is given by where RC is the series resistance of capacitor and RL is the series resistance of inductor. From the equations of QC and QL, we note that resistive component is the cause of power dissipation. Additionally, in an electrical circuit, energy loss can be reduced by adding reactive components such as capacitors or inductors and minimizing resistive components. Since obtaining a high Q factor is a usual consideration in designing WPH systems, this feature is typically included in the impedance matching network design.

4.6 SENSITIVITY

Sensitivity of a WPH system is defined as the minimum limit of incident power that is required to trigger the operation of the system. Sensitivity is quantified as follows: where is the minimum power the system requires to perform a task. The threshold voltage of CMOS technology affects sensitivity. A lower threshold CMOS is more sensitive but comes with more leakage current, which reduces the overall efficiency. **Output power**

Usually, the outcome of a WPH system is DC power, which is characterized by load

voltage VDD and current IDD. Measuring open-load voltage demonstrates the performance of WPH in general since VDD and IDD depend on load impedance. If the load is a sensor, VDD is more important than IDD while in applications like electrolysis or LED, current is the dominant parameter.

4.7 HFSS ANTENNA DESIGN

Antennas are virtually everywhere. From commercial applications such as smartphones, RFID tags, and wireless printers, to defense applications such as phased array antennas for aircraft radar systems or satellite-based, to provide integrated ground-based communication systems. Electromagnetic simulation is a valuable tool in antenna design and platform integration providing the designer the ability to virtually design and evaluate what if scenarios as well as verify the final manufactured design. ANSYS® HFSS™ excels at a wide variety of high frequency, full-wave, electromagnetic applications including antenna design and placement since it uses multiple advanced solver techniques to simulate not just the antenna but also the effects of its interaction with the entire system, including the feeding system as well as the platform.

This paper describes antenna design and simulation with ANSYS HFSS, the industry leading 3D electromagnetic (EM) simulation tool for high frequency and high-speed electronic components. Figure 1 highlights several antenna-related applications with emphasis on antennas on or around other structures. With multiple simulation technologies and powerful automated adaptive mesh refinement providing gold standard accuracy, HFSS can help antenna designers who are constantly challenged with implementing designs across more and more frequency bands inside a smaller and smaller footprint. With these additional technical challenges along with the ever-shrinking time to market, simulation with HFSS is a must-have in the antenna design and integration process. Miniaturization of the antennas, limited channel bandwidth, reduced design time, and antenna interaction with other components present stiff challenges to the design engineer. HFSS provides automatic, accurate, and efficient solutions to overcome these challenges, making it the ultimate tool of choice for antenna simulation. Basic performance characterization such as return loss, input

impedance, gain, directivity and a variety of polarization characteristics can be analyzed in HFSS. Key post-processing features such as.

4.8 SIMULATION TOOL

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS to design high-frequency, high-speed electronics found in communications systems, radar systems, advanced driver assistance systems (ADAS), satellites, internet-of-things (IoT) products and other high-speed RF and digital devices.

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 Multiphysics 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 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. Beat the competition and capture your market with Ansys HFSS.

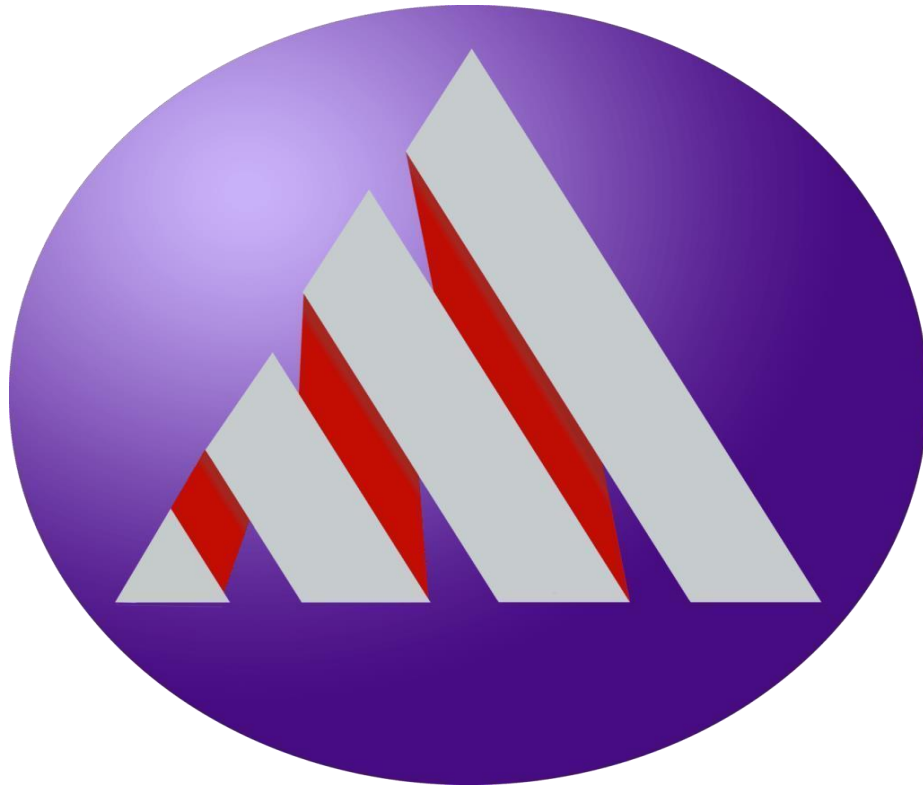


Fig.4.8 ANSYS HFSS 15.0 64 BIT

4.8.1 DESIGN MICROPATCH

ANTENNAANSOFT TERMS

The Ansoft HFSS window has several optional panels:

CHARACTERISTICS

A *Project Manager* - Project Manager Project Manager which contains a design tree which lists the structure of the project.

A *Message Manager*- Message Manager Message Manager that allows you to view any errors or warnings that occur before you begin a simulation.

A *Property Window*- Property Window Property Window that displays and allows you to change model parameters or attributes.

A *Progress Window* -Progress Window Progress Window that displays solution progress.

A *3D Modeler Window*- 3D Modeler Window 3D Modeler Window which contains

the model and model tree for the active design. For more information about the 3D Modeler Window

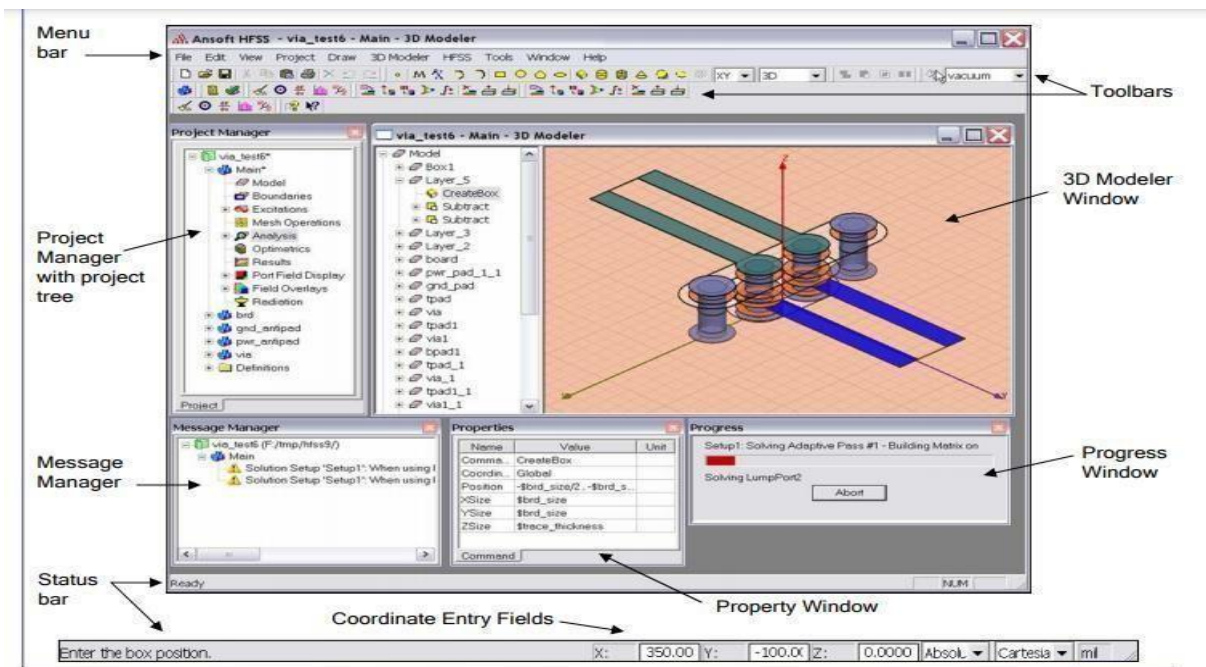


Fig.4.8.1 Design micro patch

PROJECT MANAGER

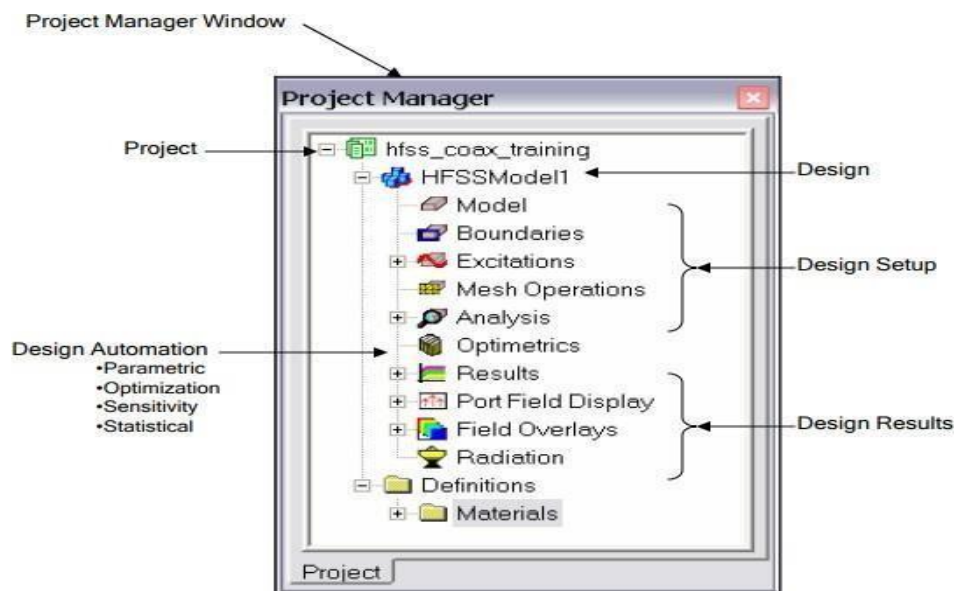


Fig.4.8.1. project manager

PROPERTY WINDOW

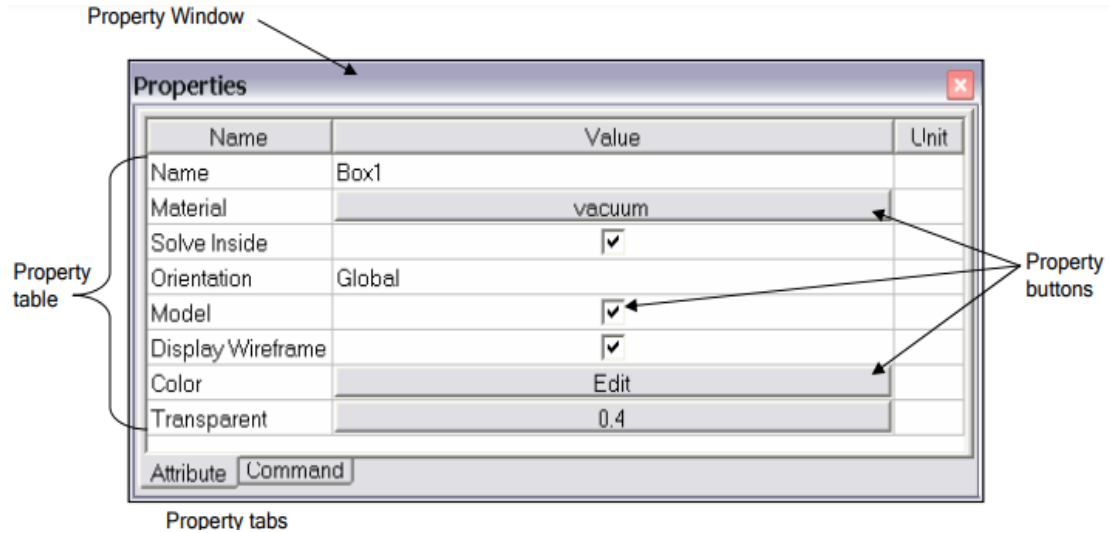


Fig.4.8.1 property window

ANSOFT 3D MODELER

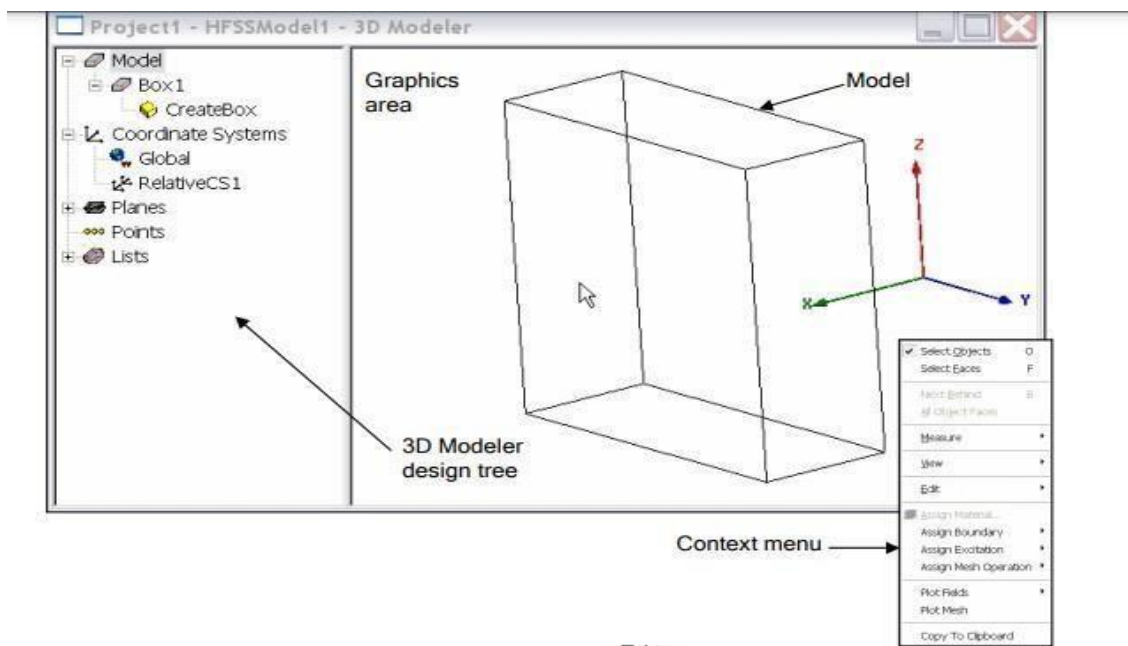


Fig.4.8.1 Ansoft 3D Modeler

4.8.2 DESIGN WINDOWS

In the Ansoft HFSS Desktop, each project can have multiple separate window.

You can have multiple projects and design windows open at the same time. Also, you can have multiple views of the same design visible at the same time.

To arrange the windows, you can drag them by the title bar, and resize them by dragging a corner or border. Also, you can select one of the following menu options: Window > Cascade, Window > Tile Vertically, or Window > Tile Horizontally.

To organize your Ansoft HFSS window, you can iconize open designs. Click the Iconize ** symbol in the upper right corner of the document border. An icon appears in the lower part of the Ansoft HFSS window. If the icon is not visible, it may be behind another open document. Resize any open documents as necessary.

Select the menu item Window > Arrange Icons to arrange them at the bottom of the Ansoft HFSS window. Select the menu item Window > Close All to close all open design. You are prompted to Save unsaved designs.

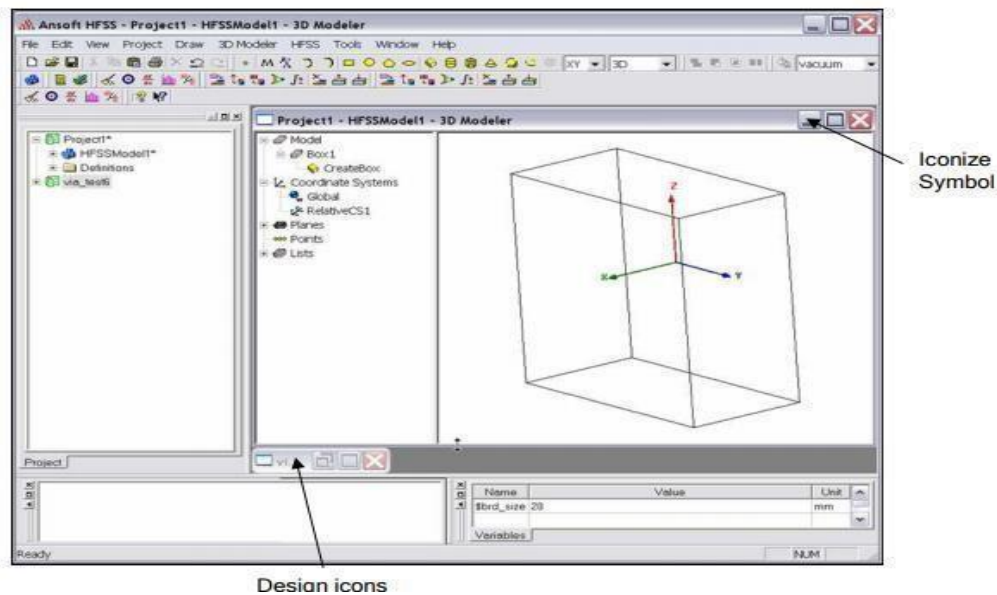


Fig.4.8.2 Design window

4.9 TOOLBARS

The toolbar buttons are shortcuts for frequently used commands. Most of the available toolbars are displayed in this illustration of the Ansoft HFSS initial screen, but your AnsoftHFSS window probably will not be arranged this way. You can customize your toolbar display in a way that is convenient for you. Some toolbars are always displayed; other toolbars display automatically when you select a document of the related type

FIG - X

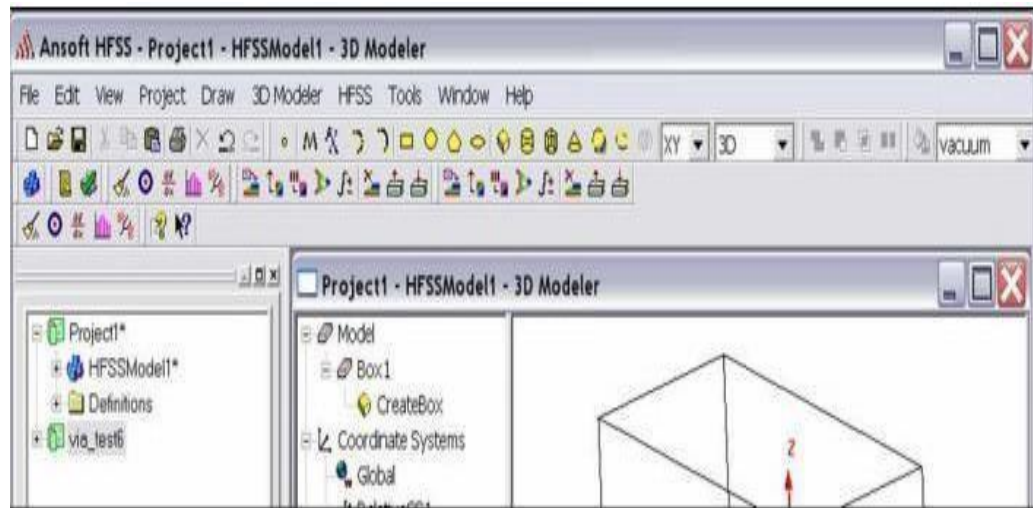


Fig.4.9 Toolbars

ANSOFF HFSS Desktop

The Ansoft HFSS Desktop provides an intuitive, easy-to-use interface for developing passive RF device models. Creating designs, involves the following

1. Parametric Model Generation – creating the geometry, boundaries and excitations
2. Analysis Setup – defining solution setup and frequency sweep Analysis Setup
3. Results – creating 2D reports and field plots Results
4. Solve Loop - the solution process is fully automated

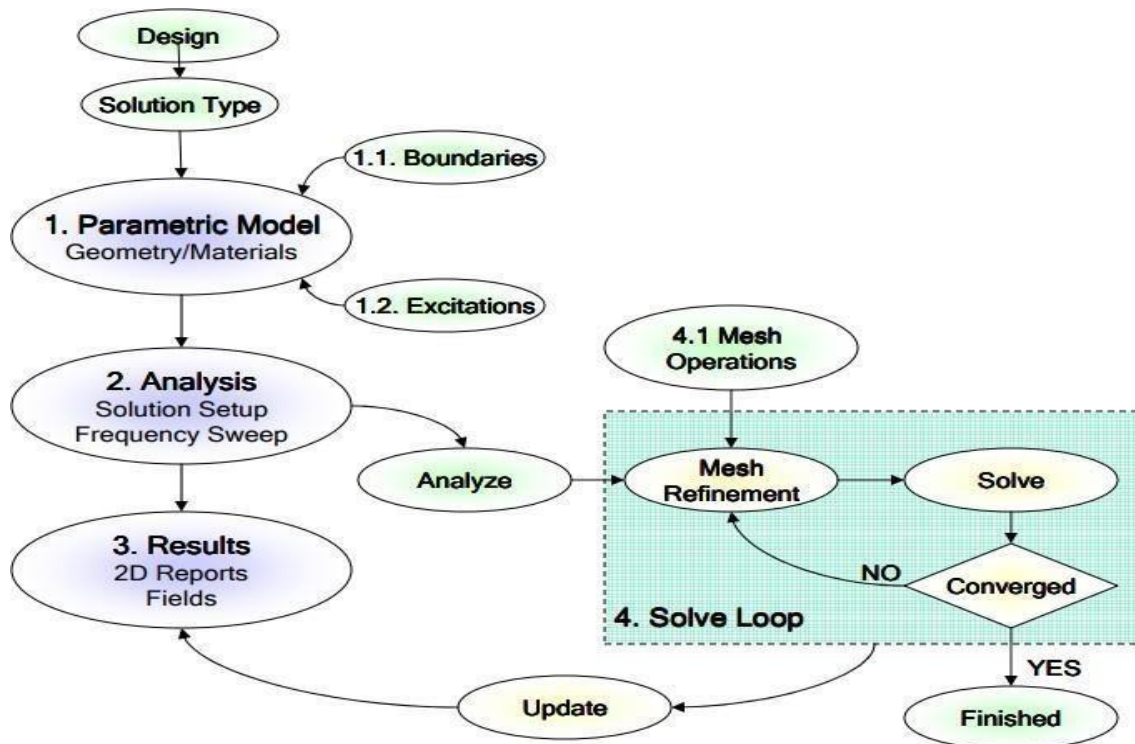


Fig.4.9 RF Device model

Opening a HFSS project

This section describes how to open a new or existing project.

Opening a New project to open a new project:

In an Ansoft HFSS window, select the menu item File > New.

Select the menu Project > Insert HFSS Design Project > Insert HFSS Design.

Opening an Existing HFSS project To open an existing project:

In an Ansoft HFSS window, select the menu File > Open. Use the Open dialog to select the project.

ect > Insert HFSS Design Project > Insert HFSS Design. Click Open to open the project

Opening an Existing Project from Explorer

You can open a project directly from the Microsoft Windows Explorer.

To open a project from Windows Explorer, do one of the following: e following Double-click on the name of the project in Windows Explorer.

Right-click the name of the project in Windows Explorer shortcut menu.

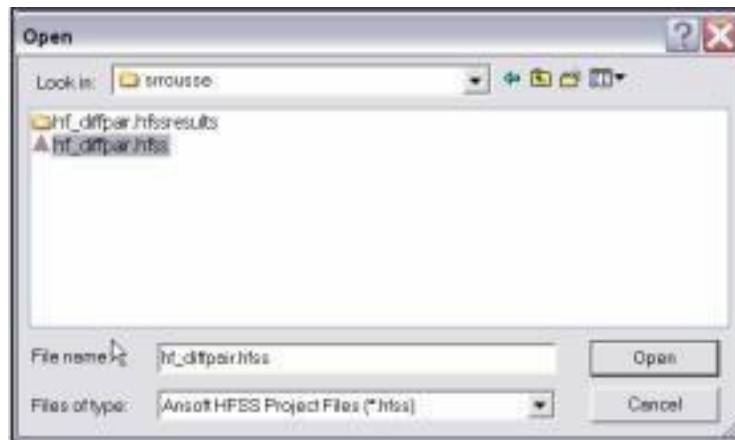


Fig.4.9 Existing project

SOLUTION TYPE

This section describes how to set the Solution Type. The Solution Type defines the type of results, how the excitations are defined, and the convergence. The following Solution Types are available:

1. **Driven Modal** - calculates the modal-based S-parameters. Driven Modal The S-matrix solutions will be expressed in terms of the incident and reflected powers of waveguide modes.
2. **Driven Terminal** - calculates the terminal-based S-parameter Driven Terminal ters of multiconductor transmission line ports. The S-matrix solutions will be expressed in terms of terminal voltages and currents.
3. **Eigenmode** – calculate the eigenmodes, or resonances, of Eigenmode a structure. The Eigenmode solver finds the resonant frequencies of the structure and the fields are those resonant frequencies.

To set the solution type:

1. Select the menu item HFSS > Solution Type
2. Solution Type Window:
 1. Choose one of the following:
 1. Driven Modal
 2. Driven Terminal
 3. Eigenmode
 2. Click the OK button

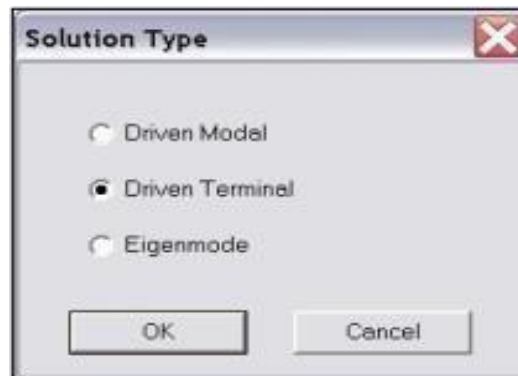


Fig.4.9 Eigenmode

PARAMETRIC MODEL CREATION

The Ansoft HFSS 3D Modeler is designed for ease of use and flexibility. The power of the 3D Modeler is in its unique ability to create fully parametric designs without editing complex macros/model history.

The purpose of this chapter is to provide an overview of the 3D Modeling capabilities. By understanding the basic concepts outlined here you will be able to quickly take advantage of the full feature set offered by the 3D Parametric Modeler. Overview of the 3D Modeler User Interface The following picture shows the 3D Modeler window.

3D Modeler Design Tree

The 3D Modeler Design Tree is an essential part of the user

interface. From here you may access the structural elements in addition to any object dependencies and attributes.

Context Menus – Context menus are a flexible way of accessing Context Menus frequently used menu commands for the current context. The contents of these menus change dynamically and are available throughout the interface by clicking the right mouse button

Graphics Area – The graphics area is used to interact with Graphics Area the structural elements.

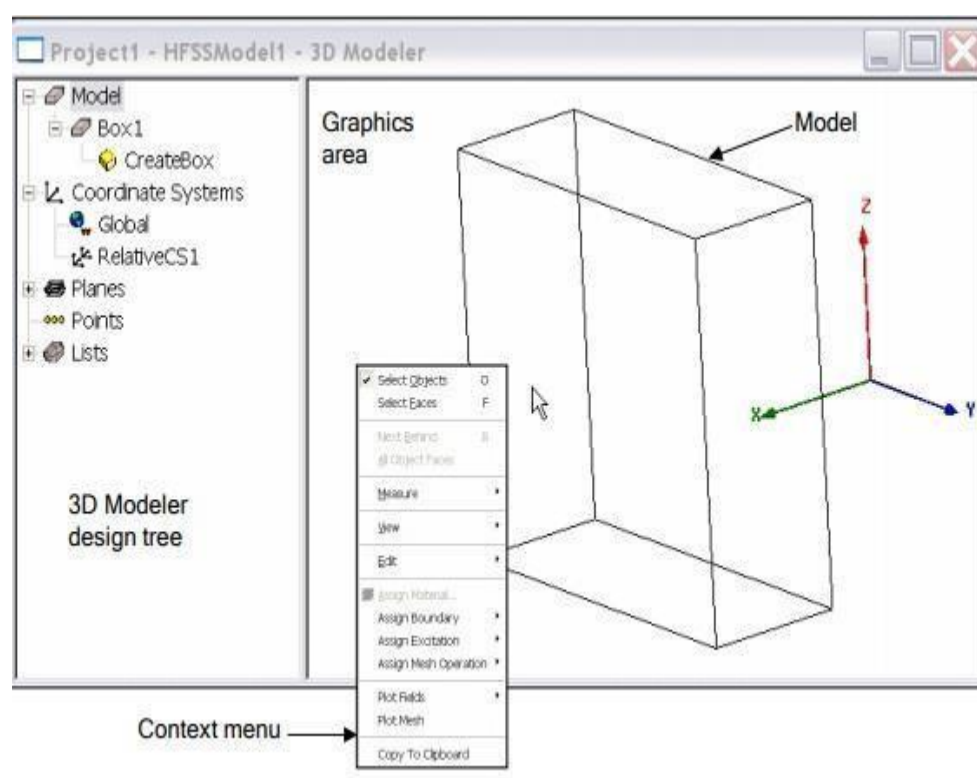


Fig.4.9 Graphics Area

When using the 3D Modeler interface, you will also interact with two additional interfaces

Property Window – The Property Window is used to view or Property Window modify the attributes and dimensions of structural objects

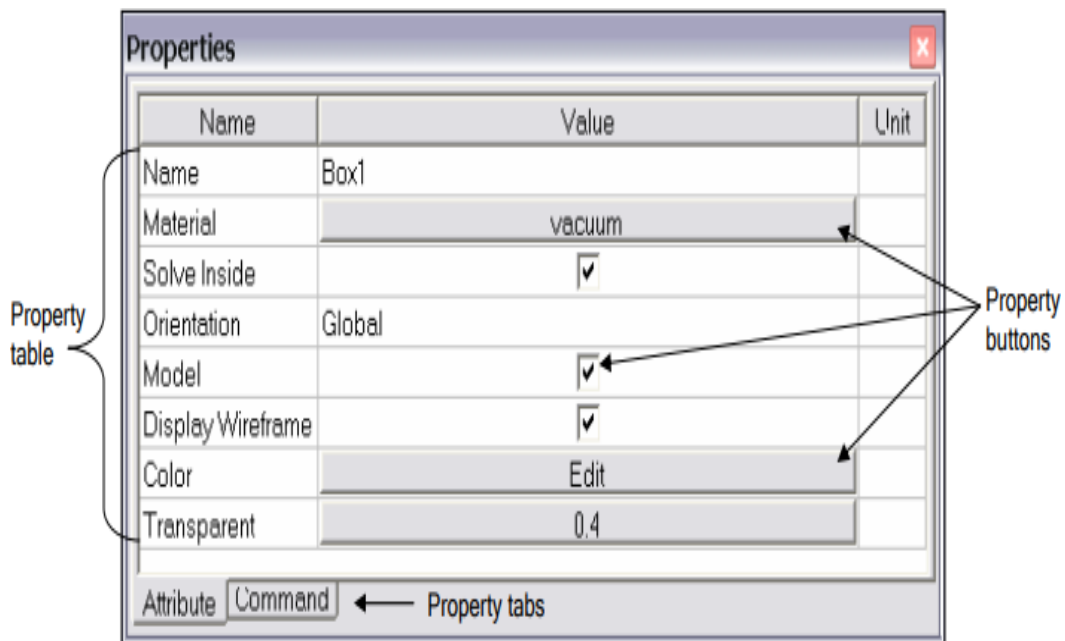


Fig. 4.9 Properties Window

Status Bar/Coordinate Entry

The Status Bar on the Ans Status Bar/Coordinate Entry of HFSS Desktop Window displays the Coordinate Entry fields that can be used to define points or offsets during the creation of structural objects

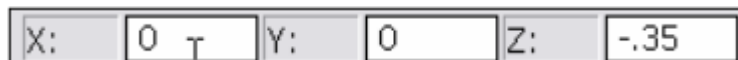


Fig.4.9 Coordinate Entry

ACTIVE CURSOR

The active cursor refers to the cursor that is available during object creation. The cursor allows you to graphically change the current position. The position is displayed on the status bar of the Ansoft HFSS Desktop Window.

When objects are not being constructed, the cursor remains passive and is set for dynamic selection. See the Overview of Selecting Objects for more details.



Fig.4.9 Active Cursor

GRID PLANE

To simplify the creation of structural primitives, a grid or drawing plane is used. The drawing plane does not in any way limit the user to two dimensional coordinates but instead is used as a guide to simplify the creation of structural primitives. The drawing plane is represented by the active grid plane (The grid does not have to be visible). To demonstrate how drawing planes are used, review the following section: Creating and Viewing Simple Structures.

Creating and Viewing a Simple Structure

Creating 3D structural objects is accomplished by performing the following steps:

1. Set the grid plane
2. Create the base shape of the object
3. Set the Height

CREATE A BOX

We will investigate creating a box to demonstrate these steps. These steps assume that project and a HFSS design have already been created. Three points are required to create the box. The first two form the base rectangle and the third sets the height.

- 1: Defines the start point of the base rectangle Point
- 2: Defines the size of the base rectangle
- 3: Defines the height of the Box

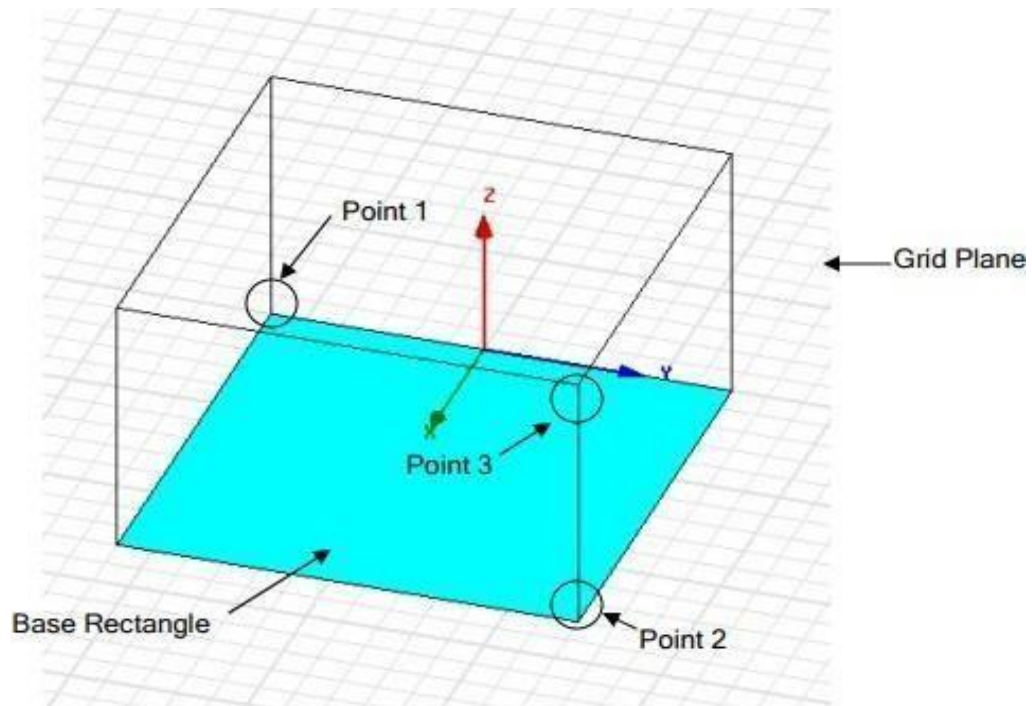


Fig.4.9 3D Structural Object

1. Select the menu item 3D Modeler > Grid Plane > XY
2. Use the mouse to create the base shape

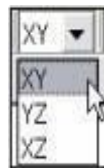


Fig.4.9 xy

1. Set the start point by positioning the active cursor and click the left mouse button.

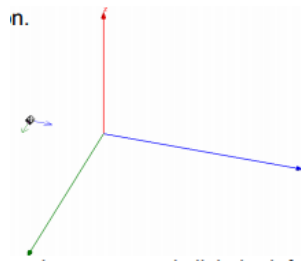


Fig.4.9 Active Cursor

1. Position the active cursor and click the left mouse button to set the second point that forms the base rectangle

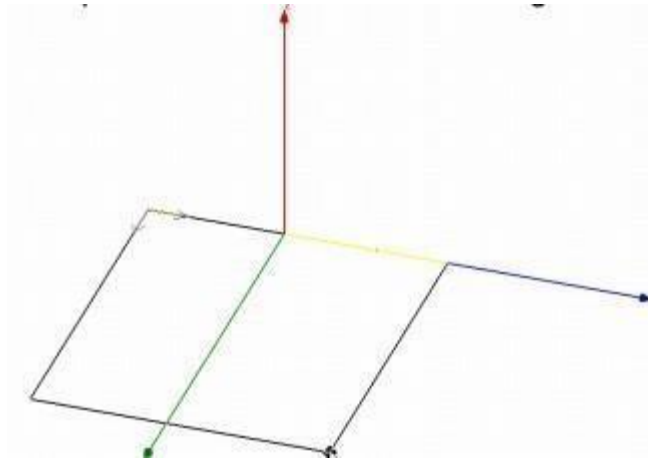


Fig.4.9.12 Base Rectangle

2. Set the Height by positioning the active cursor and clicking left mouse button

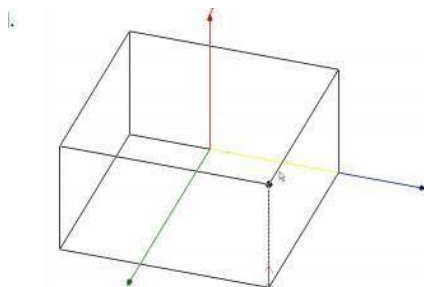


Fig.4.9 Height by Positioning

OBJECT PROPERTIES

By default the Properties dialog will appear after you have finished sketching an object. The position and size of objects can be modified from the dialog. This method allows you to create objects by clicking the estimated values using the mouse and then correcting the values in the final dialog.

The Property dialog accepts equations, variables, and units. See the Overview of Entering Parameters for more detail.

Every object has two types of properties

1. Command – Defines the structural primitive Command
2. Attributes – Defines the material, display, and solve properties

COMMAND WINDOW

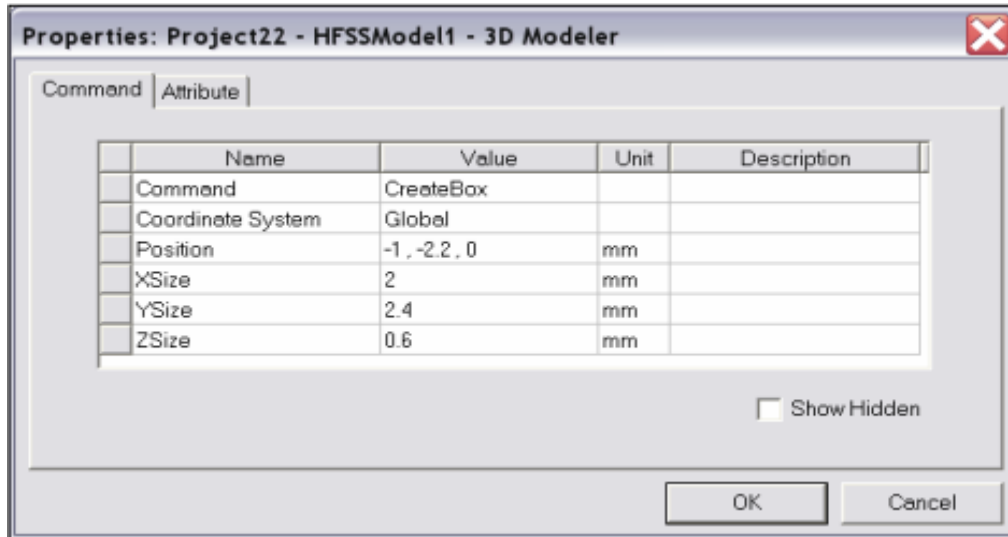


Fig.4.9 Command window

ATTRIBUTES WINDOW

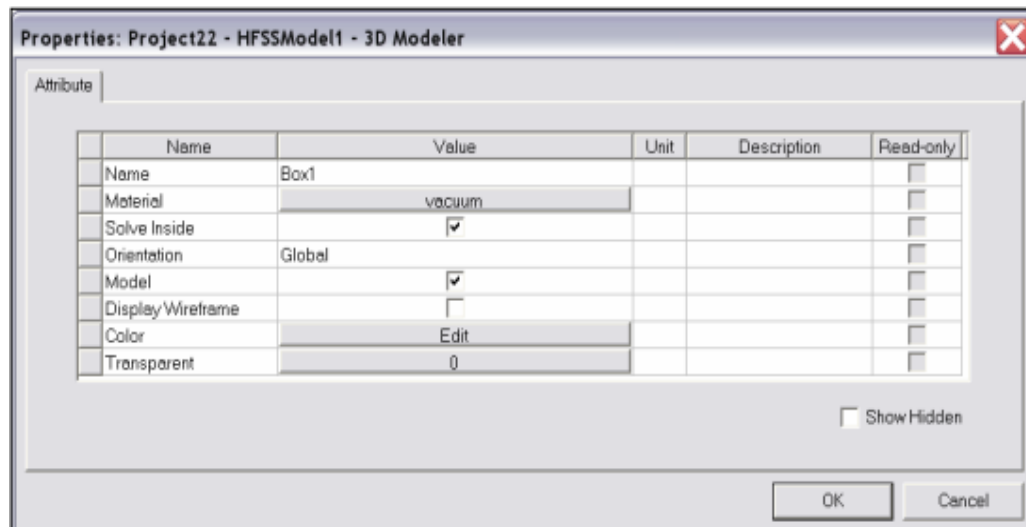


Fig.4.9 Attributes Window

4.10 CREATING SUBSTRATE

Substrate is a base or container on which microstrip patch (metallic sheet) antenna is fabricated and it plays important role in microstrip antenna functioning. The substrate in microstrip antennas is principally needed for the mechanical support of the antenna. To provide this support, the substrate should consist of a dielectric material, which may affect the electrical performance of the antenna, circuits and transmission line. A substrate must, therefore, simultaneously satisfy the electrical and mechanical requirements, which is sometimes difficult to meet. Right substrate selection is a must on the basis of cost, efficiency and size. Patch antenna is fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Substrate (dielectrics) are used for improved electrical and mechanical stability. They are used to reduce the size of the antenna (higher permittivity, lower size) and can help to produce displacement current which produces time varying Magnetic Field (by Ampere's Law). This can in turn produce time varying Electric Field (by Faraday's law) and a propagating EM field is created. Hence, a substrate can enhance antenna's radiation capability. In order to design a microstrip patch antenna at first the designer is to select the substrate material and its thickness. So, if the designer has a clear conception about the effect of changing substrate material and its thickness on the performance of the antenna, it will be easier to design an antenna. Appropriate selection of dielectric material and its thickness is an important task for designing a microstrip patch antenna.

FR4 Epoxy substrate

Position :0,0,0 **X size**:16 **Y size**:18 **Z size**: 1.6

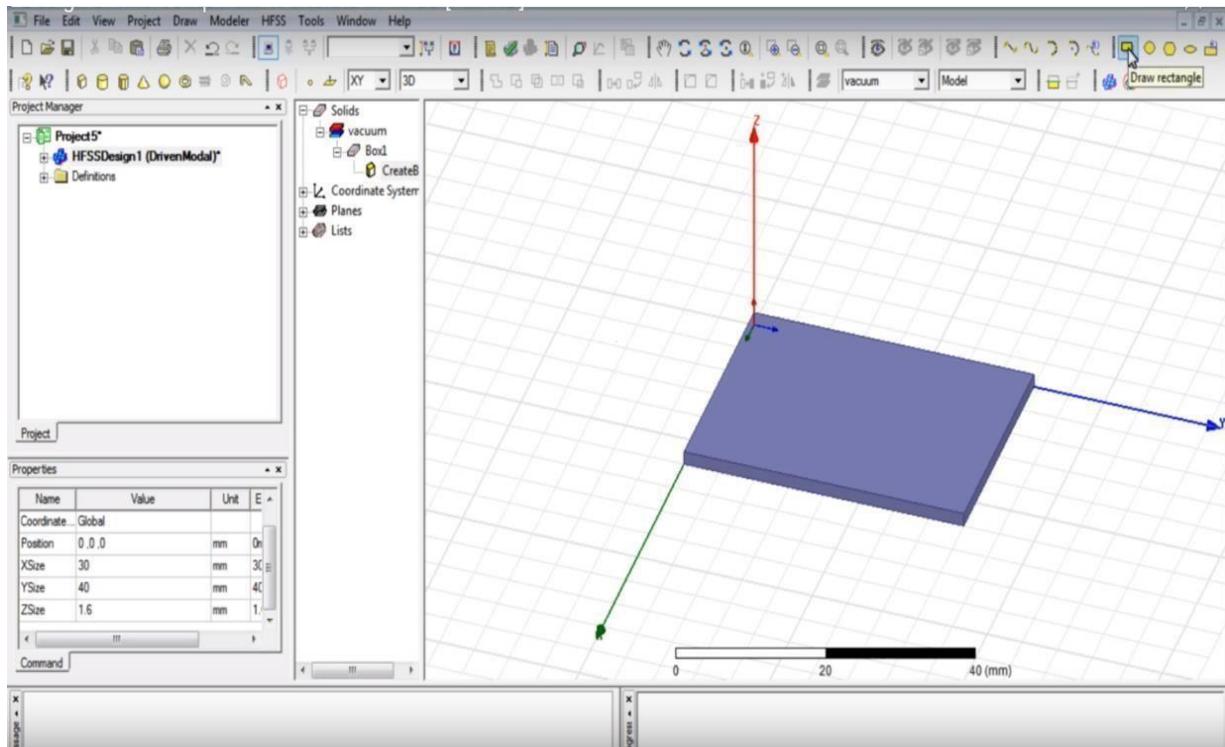


Fig.4.10 Epoxy

GROUND

A **ground plane** is an electrically conductive surface, usually connected to electrical ground. The term has two different meanings in separate areas of electrical engineering. In antenna theory, a ground plane is a conducting surface large in comparison to the wavelength, such as the Earth, which is connected to the transmitter's ground wire and serves as a reflecting surface for radio waves. In printed circuit boards, a ground plane is a large area of copper foil on the board which is connected to the power supply ground terminal and serves as a return path for current from different components on the board. Just above the substrate.

PATCH

A **patch antenna** is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a planar rectangular, circular, triangular, or any geometrical sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. The two metal sheets together form a resonant piece of microstrip transmission line with a length of approximately one-half wavelength of the radio waves. The radiation mechanism arises from discontinuities at each truncated edge of the microstrip transmission line. The radiation at the edges causes the antenna

to act slightly larger electrically than its physical dimensions, so in order for the antenna to be resonant, a length of microstrip transmission line slightly shorter than one-half the wavelength at the frequency is used. The patch antenna is mainly practical at microwave frequencies, at which wavelengths are short enough that the patches are conveniently small. It is widely used in portable wireless devices because of the ease of fabricating it on printed circuit boards. Multiple patch antennas on the same substrate called microstrip antennas, can be used to make gain array antennas, and phased arrays in which the beam can be electronically steered.

A variant of the patch antenna commonly used in mobile phones is the shorted patch antenna, or planar inverted-F antenna (PIFA). In this antenna, one corner of the patch (or sometimes one edge) is grounded with a ground pin. This variant has better matching than the standard patch. Another variant of patch antenna with the partially etched ground plane, also known as printed monopole antenna, is a very versatile antenna for dual-band operations.

- **Position: 3.5, 5, 1.6 Axis: z X size : 9 Y size: 12**

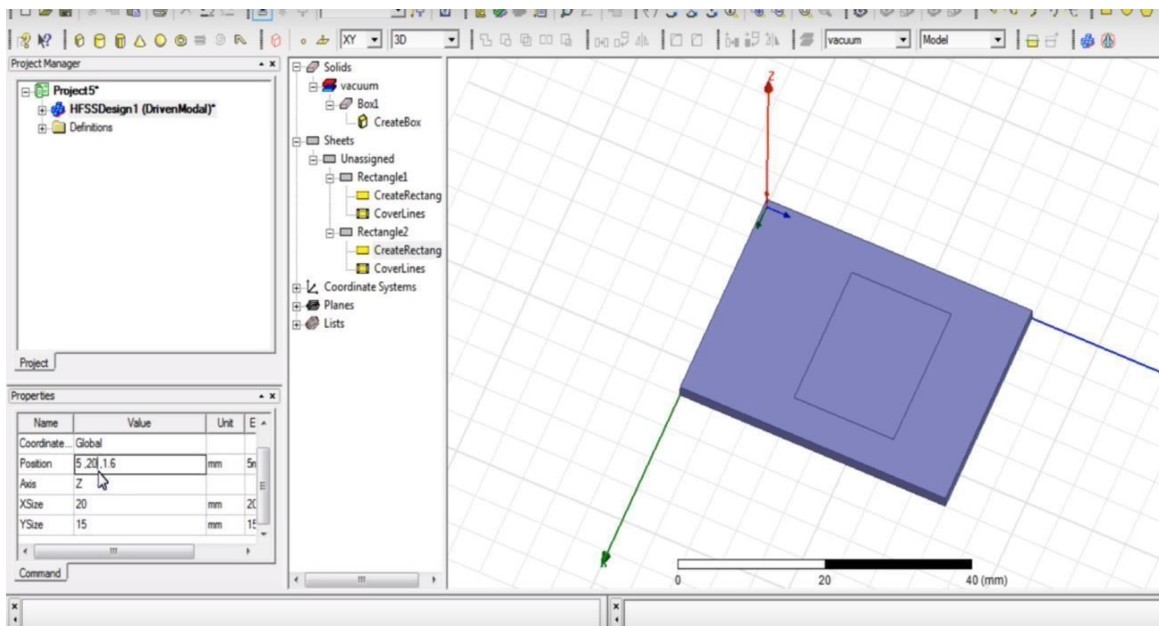


Fig.4.10. Monopole Antenna

4.11 FEED LINE

A radio antenna, the **feed line (feedline)**, or **feeder**, is the cable or other transmission line that connects the antenna with the radio transmitter or receiver. In a transmitting antenna, it feeds the radio frequency (RF) current from the transmitter to the antenna, where it is radiated as radio waves. In a receiving antenna it transfers the tiny RF voltage induced in the antenna by the radio wave to the receiver. In order to carry RF current efficiently, feed lines are made of specialized types of cable called transmission line.

Particularly with a transmitting antenna, the feed line is a critical component that must be adjusted to work correctly with the antenna and transmitter. Each type of transmission line has a specific characteristic impedance. This must be matched to the impedance of the antenna and the transmitter, to transfer power efficiently to the antenna. If these impedances are not matched it can cause a condition called standing waves on the feedline, in which the RF energy is reflected back toward the transmitter, wasting energy and possibly overheating the transmitter. This adjustment is done with a device called an antenna tuner in the transmitter, and sometimes a matching network at the antenna.

Position: 7,0,1.6

Axis: z

Xsize: 2

Y size: 5

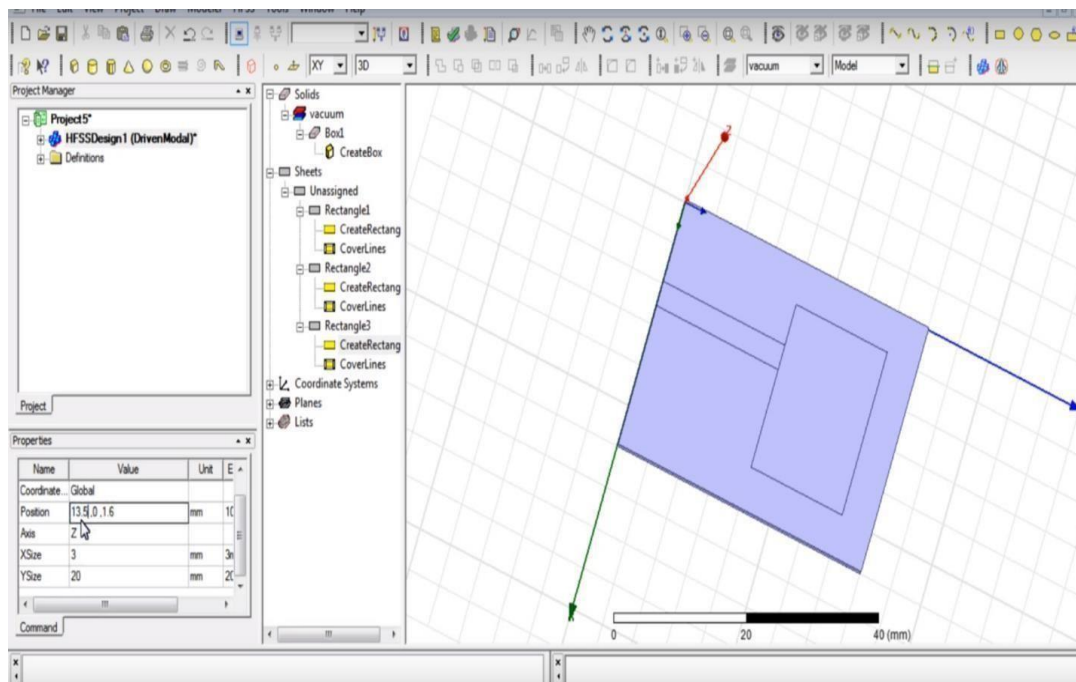


Fig .4.11 Antenna Tuner

PORT

An antenna port is generally used as a generic term for signal transmission under identical channel conditions. For each LTE operating mode in the downlink direction for which an independent channel is assumed (e.g., SISO vs. MIMO), a separate logical antenna port is define.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

Designing and fabricating an RF energy harvesting antenna involves several factors such as frequency range, antenna type, polarization, impedance matching, and power conversion efficiency, among others. Additionally, the choice of materials, manufacturing process, and testing procedures can also influence the performance of the antenna

FEED POINTS TO TAKE OUTPUT FROM ANTENNA

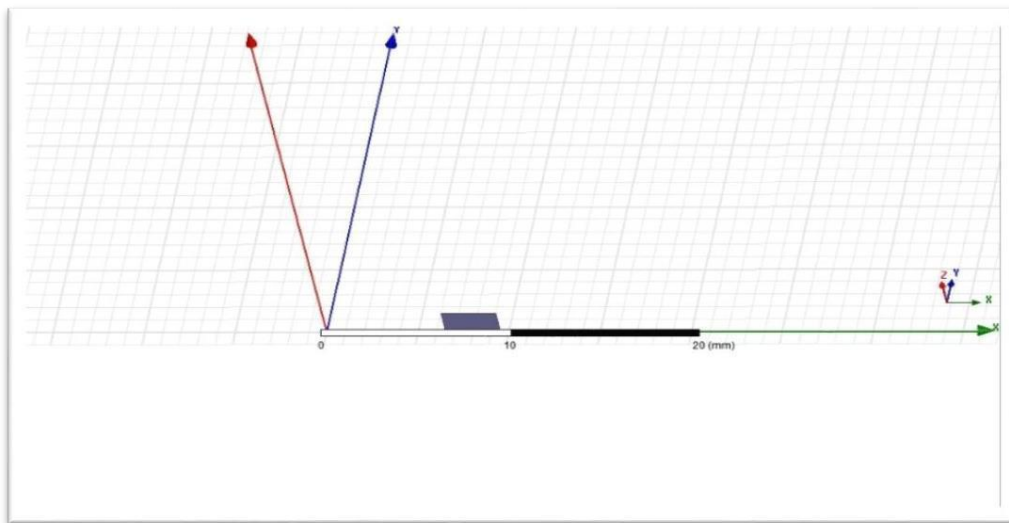


Fig.5.1 Feed Points

GROUND PLANE

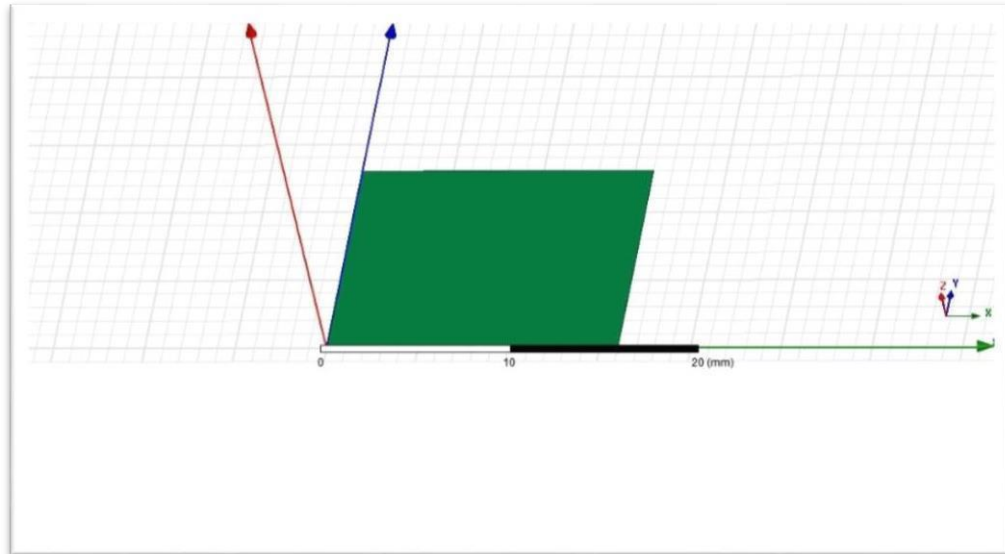


Fig.5.1 Ground plane

PATCH ANTENNA

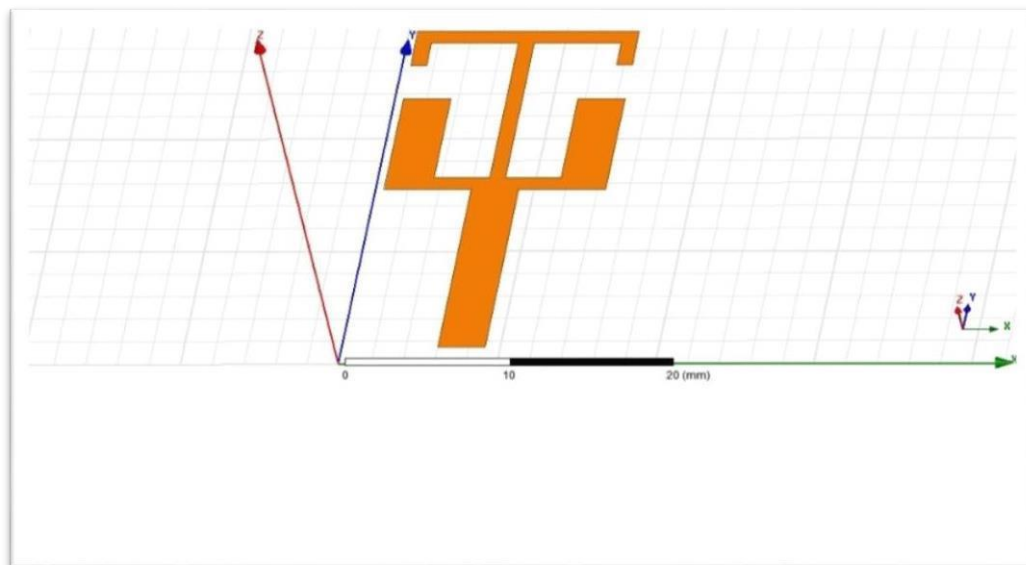


Fig.5.1 Patch Antenna

SUBSTRATE

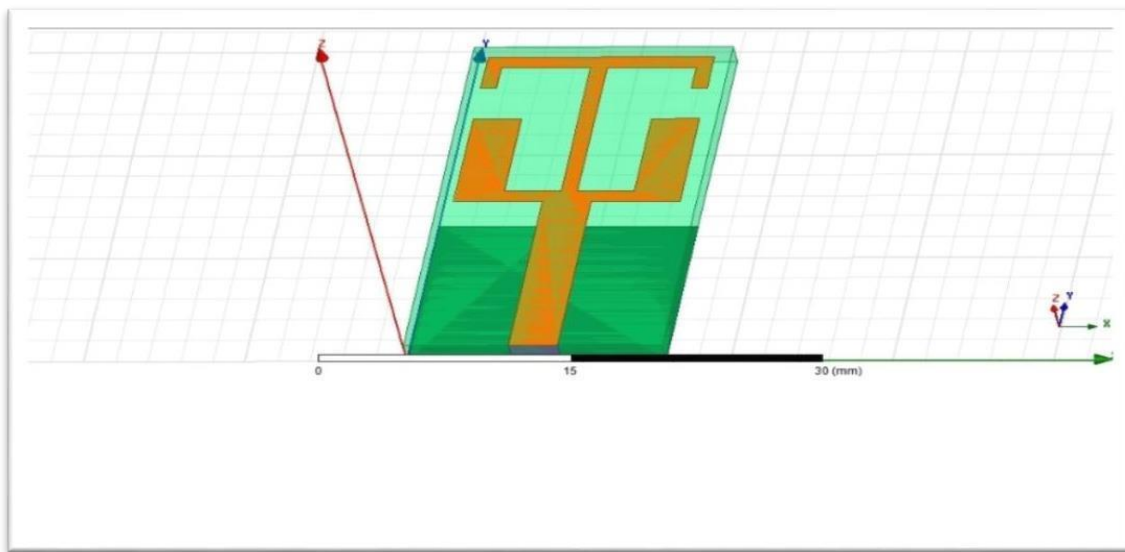


Fig.5.1 Substrate

S11

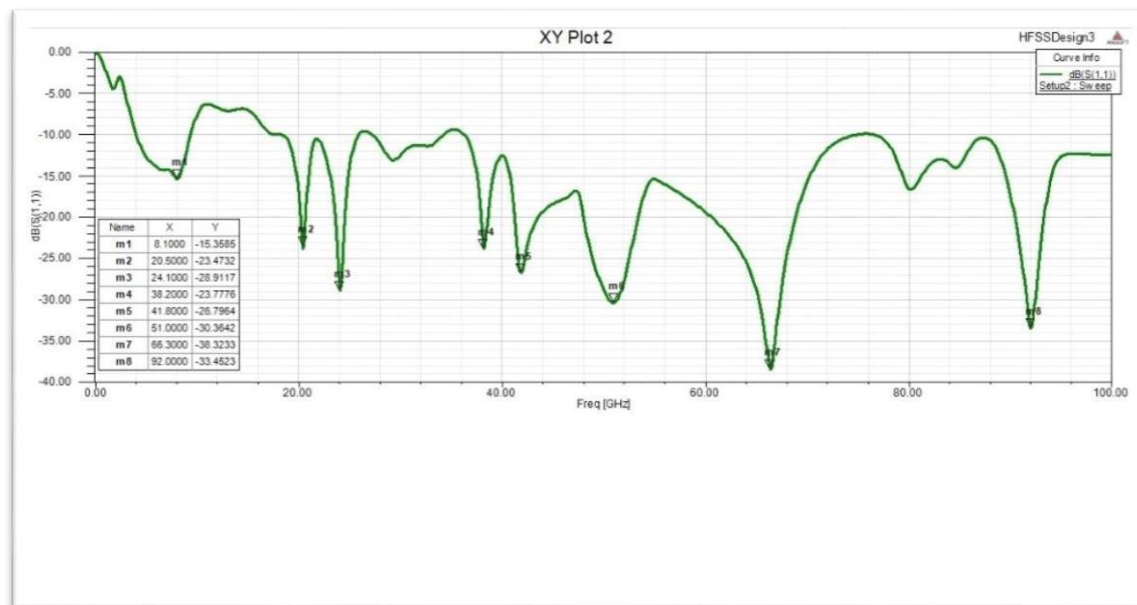


Fig.5.1 S11

TOP VIEW

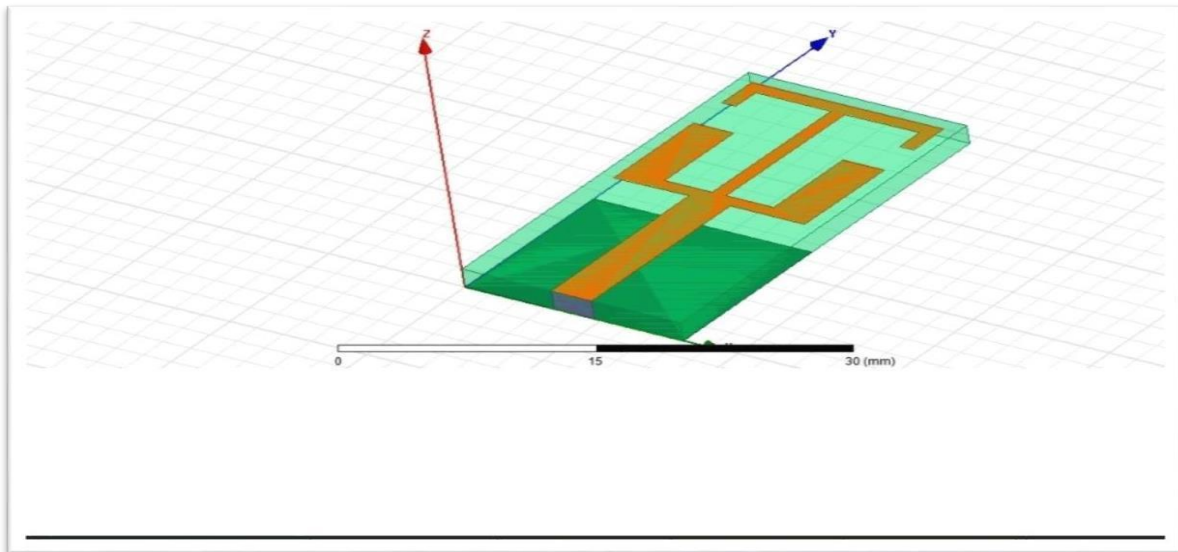


Fig.5.1 Top View

VSWR

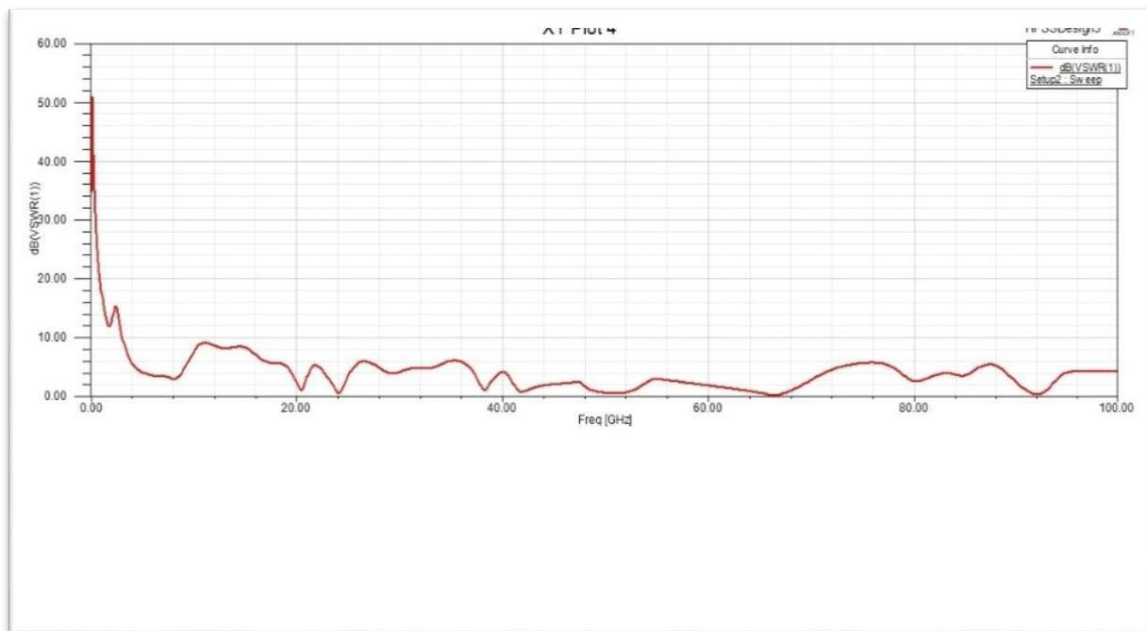


Fig.5.1 VSWR

RADIATION BOX

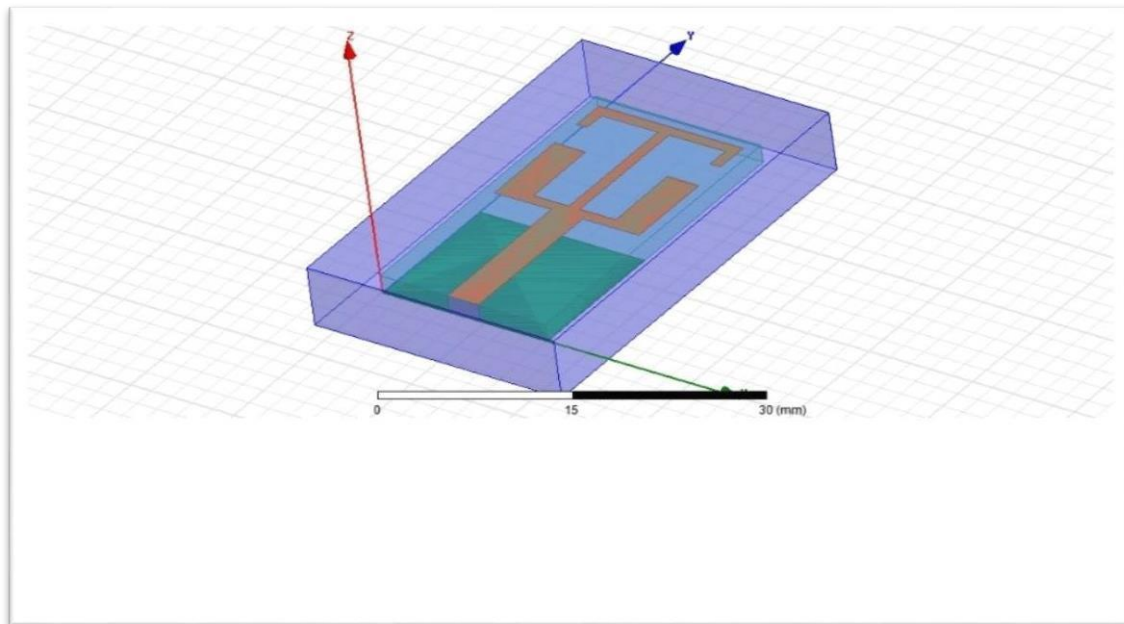


Fig.5.1 Radiation Box

Therefore, to provide a result for the design and fabrication of an RF energy harvesting antenna, I would need more specific details about the project requirements and constraints, such as the operating frequency range, the available space for the antenna, the desired power output, and the environment in which the antenna will operate.

5.2DISCUSSION

Rf energy harvesting antennas are a type of antenna that can convert ambient electromagnetic radiation, such as radio waves, into usable electrical energy. The design and fabrication of RF energy harvesting antennas involves several considerations that are critical to the performance of the antenna.

The first consideration in designing an RF energy harvesting antenna is the frequency range of the desired signals to be harvested. Different frequencies require different antenna dimensions, shapes, and materials. Therefore, the first step in designing an RF energy harvesting antenna is to determine the frequency range of

the signals to be harvested

Once the frequency range has been determined, the next step is to choose the type of antenna. There are many types of antennas that can be used for RF energy harvesting, including dipole, patch, loop, and microstrip antennas. Each type of antenna has its own advantages and disadvantages, so it is important to choose the one that is best suited for the specific application.

After choosing the type of antenna, the next step is to optimize the design parameters of the antenna. This includes determining the size, shape, and orientation of the antenna. The aim is to maximize the amount of energy that can be harvested from the ambient electromagnetic radiation

The fabrication of the RF energy harvesting antenna involves several steps, including choosing the appropriate substrate material, printing the antenna on the substrate using a suitable manufacturing process such as screen printing, and then adding any necessary components such as matching networks, filters, and rectifiers.

Testing and validation of the antenna performance is critical to ensure that it meets the desired specifications. This involves measuring the antenna's radiation pattern, gain, and efficiency, as well as its ability to harvest energy from the ambient electromagnetic radiation.

In summary, the design and fabrication of a RF energy harvesting antenna requires a thorough understanding of the frequency range, type of antenna, optimization of design parameters, substrate material, manufacturing process, and testing and validation of performance

CHAPTER 6

CONCLUSION

A microstrip antenna with capacitive feed strip suitable for dual band applications is simulated and measured which covers both GSM (1800) and ISM (2.4) bands.

The results obtained indicate good performance of proposed antenna for required frequency range, return loss better than 12dB with impedance close to 50 ohm and directional radiation pattern.

The parametric study is performed in order to understand the characteristics the proposed antenna.

The return loss radiation pattern, gain is studied too. The simulation returns loss indicates the suitability if this antenna for WLAN applications

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