Chapter 1

INTRODUCTION

Wireless power transfer (WPT or wireless charging) is a technology that allows the transmission of energy through an air gap to a load without any interconnecting cables. Wireless Power Transfer enables the delivery of power over an air gap. Without physical connections or cables, WPT may supply power from an AC source to suitable batteries or devices. WPT can refuel cellular phones, tablets, drones, automobiles, and even transportation-related equipment. Wireless Power Transfer has a wide range of applications since it may be utilized in a variety of settings, including the automation of homes and businesses, security, and safety. This can be utilized in locations where the power source is scarce or unavailable or where the wires or cables are impractical or uncomfortable.

RF to DC is the part of Wireless Power Transfer in which data or power can be transferred through radio frequency and converted to DC voltage. The conversion must go through steps like rectification, amplification, filtering, and DC-to-DC conversion to provide the desired output. The transmitted RF signal from the transmitting antenna is received by the receiving antenna, and the received AC signal is fed to the rectifier which converts the AC input into DC. The DC signal is then fed to the DC-to-DC converter and is tuned to a voltage suitable for the required device. The goal of our project is to build an antenna suitable for the efficient transfer of power and find a suitable rectifier circuit that will provide an efficient output, for the suitable rectifier few of the rectifiers will be simulated using an EDA tool the output of each rectifier will be measured and an efficient one will be selected.

Antennas are very important in the field of telecommunications and wireless communication systems. Their role is crucial because they efficiently transmit and receive electromagnetic waves. Antennas are fundamental elements in various wireless communication technologies such as radio, television, satellite, and cellular networks. These technologies enable long-distance communication without physical connections, facilitating global connectivity and information sharing. The parameters of the antenna play an important role in the RF-to-DC as the whole circuit depends on the efficiency of the received power, the dimensions of the antenna for the required frequency are calculated the shape and size of the antenna will determine the efficiency and the parameters of the antenna

1.2 Structure of Report

Chapter 1: This chapter deals with the introduction to Wireless Power Transfer (WPT), RF-to-DC conversion, and antennae.

Chapter 2: This chapter describes the literature survey done on the concerned topic. The proposed system is also introduced in this chapter. The scope and the motivation behind this project are also discussed.

Chapter 3: It describes the domain chosen which is energy harvesting, different types of energy harvesting techniques are discussed. The merits and application of RF-to-DC conversion in Wireless Power Transfer.

Chapter 4: This chapter explains the description of the software used, its advantages and its applications were also discussed

Chapter 5: System implementation using block diagram, rectifier circuit and antenna's designs and parameters was discussed in this chapter.

Chapter 6: The chapter concludes and describes the future enhancement of the proposed work. The output of the antenna and rectifier is displayed.

Chapter 7: The chapter concludes and describes the future enhancement of the proposed work.

Chapter 2

LITERATURE SURVEY

A literature review is a survey on the research topic and the depth of information to be studied. It provides an overview of current knowledge and allows us to explore its implementation and technologies used which can be helpful in the implementation of the topic. The literature review helps us to get started with the project and gives us an idea about where and how to get started.

2.1 Literature Review

[3] In this paper, they have revealed four different voltage multiplier rectifiers using a first-order L-matching network for energy harvesting in medical devices like implants such as deep brain stimulators among them 2-Stage charge pump rectifiers was having better conversion efficiency.

[4] This paper describes a low–power head mountable implant like DBS which is operated with harvested RF energy. In this, they have generated electrical energy through a mini solar panel which is used to operate medical implants like Deep brain stimulator devices. This device consists of a power management unit, a low-power microcontroller, and a constant current source. This can supply the constant current source required by implanted devices like DBS.

[6] This paper presents a circular meander dipole antenna for a head-mountable implant such as DBS which had a bandwidth of 15MHz at a return loss of -10db at the ISM band of 915MHz which is the ideal frequency for energy harvesting in medical devices. The presence of a hat model which is near the antenna altered its parameters. Which in turn results in a shift in resonance frequency as well as a reduction of antenna gain.

[8] This paper presents a survey of microstrip patch antenna parameters and feeding techniques. Depending on the application, different feeding techniques have different factors. Some parameters show the output characteristics of the antenna, such as gain, VSWR, bandwidth, and return loss. The latest developments in MSTPA are discussed, as well as the impact of patch shape and dimensions, as well as substrate, on obtaining the proper output parameters.

[9] In this paper work an on-chip RF to DC power converter is designed for the application in bio-medical devices like DBS. A DC-to-DC switched capacitor is used to prevent the issue of large off-chip inductors. To Concentrate and improve the efficiency of

the received input power, a rectifier which is improved has been implemented in this device to eliminate reverse leakage associated with cross-coupled topology.

[11] This study introduces an RF-to-DC converter circuit utilizing 0.13 μm CMOS technology to harvest RF energy. The circuit includes a rectifier for converting the RF input signal into a DC voltage, which is then fed into a charge pump to increase the DC voltage output. The output voltage is regulated by a regulator to produce the necessary DC voltage. Simulation results demonstrate that the proposed design can convert RF input signals ranging from 900 MHz to 2400 MHz with a power of -16.5 dBm into a 1.25 V DC output.

2.2 Motivation

RF-to-DC conversion opens up a wide range of opportunities in wireless power technologies, energy harvesting, and green energy by reducing the implementation of wires and batteries in every device hence reducing the cost and maintenance. Battery-powered devices like sensors, and speakers that rely on low power input can be continuously charged without the need for replacement of batteries or recharging the batteries which can reduce the cost and energy.

Another motivation is the reduction in medical procedures and costs, some of the implants required for the smooth functioning of the body part require repeated surgery for either the replacement of the battery or recharging the batteries. Repeated surgeries can be avoided by introducing wireless charging of the implants by the process of RF charging, hence reducing the cost and repeated surgery and saving time for the surgeons.

2.3 Scope of project

As the world is moving towards becoming wireless it will be necessary to implement wireless charging of the devices. It will be needed where the implementation of wires is impractical and difficult. The continuous charging of the device will be more practical when there is a need for the operation of safety and medical devices like sensors and implants which needs to be operating continuously for the safety of the people. For ease of use and comfort of people, this system can also be implemented in the home automation system and home security system to eliminate the need for frequent battery replacement and eliminate wired power connections.

Since sustainability and renewability are necessary in today’s world eliminating the batteries and wastes produced by it. The damages done by the batteries can lead to soil pollution like lead contamination which can be reduced by using rechargeable batteries charged by the wireless power transfer or powering the device by using this wireless power transfer technique.

2.4 Problem statement

The low power devices like implants need frequent replacement of the batteries for which repeated surgeries and medical procedures need to be done which can lead to irritation and or other complexity in the operated area. The introduction of wireless power transfer can wirelessly charge the rechargeable battery or power the implants eliminating the need for surgeries.

Sensors implemented in the home security system if inoperable due to low battery scenarios can be dangerous as they won’t be able to detect dangers and can lead to break-ins, and housefires. This can be eliminated by the introduction of wireless power transmission which can feed power continuously to the device hence keeping the home safe.

Chapter 3

Energy Harvesting

Energy harvesting is the process of capturing energy through the environment and converting it into useful energy necessary for the operation of the device without the need for a conventional power source, it eliminates the need for wires and allows powering or charging of the device eliminating the need for continuous replacement of the batteries. Energy harvesting can be derived from light sources, radio energy, vibration or pressure, temperature differentials, and magnetic energy. These energies in the free space can be captured by numerous devices like,

- Photovoltaic cells capture the sunlight into electrical energy.
- Antenna which captures the radio frequency and converts it into necessary power required by the device.
- Thermoelectric generator that converts heat directly into electricity.
- Piezoelectric generator, when mechanical pressure is applied to the material electric charges are generated.
- Magnetic generator which generates electric energy by using the mechanical energy generated by the magnets.

Wireless power transfer (WPT) allows power to be delivered across the air gap without any need for live wires. The requirement for wireless power transfer is increasing day by day as the implementation of wires in the devices is reduced and most of the devices are switching to wireless technology

3.1 Merits

Energy harvesting technology has several advantages that make it beneficial for a variety of applications. Here are some key advantages of energy harvesting technology:

Renewable Energy: Energy harvesting technologies utilize ambient energy sources such as solar, wind, thermal, or kinetic energy that are renewable and readily available in the environment. They provide a sustainable alternative to traditional energy sources and help reduce dependence on fossil fuels.

Cost-effective: Energy generation eliminates the need for batteries or external power sources or significantly reduces them. Once an energy harvesting system is in place, it can provide continuous power without the recurring costs of traditional power sources. This is especially beneficial in remote or hard-to-reach locations where battery replacement can be difficult or expensive.

Environmentally Friendly: Energy harvesting technology produces clean energy with minimal environmental impact. By using renewable energy, they reduce greenhouse gas emissions and contribute to a greener, more sustainable future.

Increased efficiency and autonomy: Energy harvesting allows devices to become self-sufficient by generating electricity from their environment. This enhanced autonomy eliminates the need for frequent manual intervention or recharging, increasing the overall efficiency and reliability of the device. This is especially valuable for wireless and IoT devices that require long-term operation.

Scalability and versatility: Energy harvesting technologies can be designed to accommodate different scales and applications. Energy harvesting can be adapted to different energy needs, from small applications such as powering portable devices or sensors to large applications such as street lighting or building energy management.

Extended Lifespan: By harnessing energy from the environment, energy harvesting technologies can extend the lifespan of devices and systems. This is especially true for battery-powered devices that are constrained by degraded battery performance and limited energy capacity. Energy harvesting can compensate for changes in batteries and even make them redundant.

Reduced maintenance: Energy harvesting systems typically have fewer moving parts and require minimal maintenance than traditional energy systems. This reduces the complexity and cost of servicing and maintaining the equipment, which increases reliability and reduces downtime.

Design flexibility: Energy harvesting technologies offer design flexibility as they can be incorporated into different shapes and materials. For example, solar cells could be embedded in flexible substrates, allowing them to be seamlessly integrated into clothing or building materials.

3.2 Applications

Wireless sensor network:

Wireless sensor networks (WSNs) play a vital role in various fields such as environmental monitoring, structural health monitoring, and industrial automation. However, the limited battery life of sensor nodes is a major challenge, and energy harvesting technologies such as solar, vibration, and thermal harvesting offer sustainable solutions by continuously replenishing the energy reserves of sensor nodes. This section examines the integration of energy harvesting in WSNs, as well as practical and design considerations.

Internet of Things (IoT):

The rapid growth of IoT devices requires scalable and durable power solutions. Energy harvesting offers a viable option for powering IoT devices in smart homes, agriculture, healthcare, and transportation. This paper explores the potential of energy-harvesting technologies for IoT applications, including energy-efficient sensor nodes, self-powered wearable devices, and energy-efficient protocols.

Wearable Electronics:

Wearable electronic devices such as smartwatches, fitness trackers, and health monitors have grown in popularity in recent years. However, the need for frequent charging limits their usability. Energy harvesting technologies offer an alternative, harnessing the energy generated by human motion, solar radiation, or thermal gradients. This section examines progress in energy harvesting for wearable devices and discusses challenges related to miniaturization, efficiency, and user convenience.

Buildings and Infrastructure:

Energy harvesting can be integrated into the built environment to improve energy efficiency and sustainability. This paper examines the application of energy harvesting in smart buildings, smart cities, and infrastructure systems. Topics it covers include solar-powered buildings, piezoelectric materials that harvest energy from structural vibrations, and harvesting kinetic energy from pedestrian motion.

Automotive and Transportation:

The automotive and transportation industries use energy harvesting technologies to improve fuel efficiency, reduce emissions and improve the overall performance of vehicles. This section focuses on applications of energy harvesting in hybrid and electric vehicles, regenerative braking systems, tire pressure monitoring, and autonomous wireless sensor systems for transportation infrastructure.

Environmental monitoring:

Energy harvesting plays a vital role in environmental monitoring systems deployed in remote or hard-to-reach locations. These systems require a long-term autonomous operation, which can be achieved by harvesting energy from sources such as the sun, wind, or environmental vibrations. Energy harvested from the environment powers sensors to monitor parameters such as air quality, water quality, weather conditions, and wildlife tracking.

Healthcare and Biomedical Devices:

Energy harvesting offers enormous potential for healthcare and biomedical applications where battery replacement or recharging may be impractical or impractical. Energy harvesting technologies allow implanted medical devices such as pacemakers and neurostimulators to operate using energy from the body, such as body heat or kinetic energy. Additionally, wearable health monitors and drug delivery systems could benefit from energy harvesting, ensuring continuous operation without frequent battery replacements.

Consumer electronics products:

Energy harvesting is increasingly integrated into consumer electronic devices to improve usability and reduce the environmental impact of batteries. Examples include solar-powered calculators and keyboards, self-powered electric energy-harvesting remote controls, and self-charging wireless computer peripherals. Using energy harvesting technology, these devices can operate autonomously, reducing reliance on disposable batteries or frequent recharging.

Agricultural applications:

Energy harvesting technologies are used in agriculture to power a variety of systems and devices. For example, solar panels can be used to generate energy for irrigation systems, wireless soil and environmental sensors, and livestock tracking equipment. Energy harvesting helps optimize resource use, increase crop yields, and enable precision farming practices by powering distributed sensor networks and autonomous farming equipment.

Industrial automation and structure monitoring:

Energy harvesting can be used in industrial settings to power wireless sensor networks used in condition monitoring, asset tracking, and predictive maintenance. Harvesting energy from ambient vibration or heat allows for continuous monitoring of device health and performance without requiring battery changes or wiring. Additionally, energy harvesting technologies enable structural health monitoring systems to monitor the integrity of bridges, buildings and other critical infrastructure in real-time.

Military and Defense Applications:

Energy harvesting is important to military and defense applications, where the ability to power autonomous systems and sensors is critical. Energy harvesting technology is used to power equipment carried by soldiers, long-range surveillance systems, unmanned aerial vehicles (UAVs), and unmanned ground vehicles (UGVs). By harvesting energy from the environment, these devices can operate for extended periods without human intervention or frequent battery changes

Chapter 4

SOFTWARE DESCRIPTION

Keysight Advanced Design System (ADS) is a powerful electronic design automation (EDA) software suite for the design, simulation, and analysis of high-frequency and high-speed electronic components and systems. It is widely used by engineers in the RF (radio frequency), microwave, wireless communications, aerospace, and defense industries.

1. Design and Simulation Capabilities:

- ADS provides comprehensive design and simulation possibilities for the development of complex electronic systems. It enables engineers to design and analyze circuits, subsystems, and complete systems, including RF/microwave circuits, high-speed digital designs, and mixed-signal circuits.

- The software provides a wide range of simulation engines and models to accurately represent the behavior of various components such as transistors, amplifiers, filters, mixers, antennas, transmission lines, etc. It supports linear and nonlinear simulations, enabling detailed analysis of system performance.

2. Integrated design environment:

- ADS provides an integrated design environment that supports a seamless design process and collaboration between different design stages. It provides a user-friendly interface with customizable toolbars, menus, and windows allowing engineers to easily navigate and access various functions.

- The software enables schematic capture, layout design, and electromagnetic (EM) simulation in the same environment. This integration simplifies the design process and reduces the possibility of errors or inconsistencies between different design stages.

3. Advanced Optimization and Yield Analysis:

- ADS includes powerful optimization algorithms that allow engineers to optimize their designs for various performance metrics. It automatically adjusts component values, dimensions, and other design parameters to meet the required specifications.

- The software also provides yield analysis capabilities, enabling engineers to evaluate the impact of manufacturing process variations on system performance. This helps improve the robustness and yield of designs before they enter the production phase.

4. Model and data management:

- ADS provides efficient model and data management capabilities, enabling engineers to organize and reuse models, components, and simulation results. This helps maintain consistency between projects, share designs with colleagues, and leverage existing knowledge and expertise.

- The software supports standard model libraries and data formats, is compatible with other EDA tools, and improves interoperability with third-party software.

5. System-level design and verification:

- ADS provides system-level design and verification capabilities, enabling engineers to analyze the behavior of complete electronic systems. It allows the integration of multiple subsystems taking into account interaction, interference, and signal integrity issues.

- The software provides advanced signal integrity analysis, including eye diagram analysis, bit error rate (BER) estimation, and power integrity analysis. This helps ensure robust and reliable system performance in high-speed digital and mixed-signal designs.

4.1 Applications

RF and Microwave Circuit Design:

ADS is widely used to design RF and microwave circuits such as amplifiers, filters, oscillators, mixers, and matching networks. Engineers can simulate and optimize these circuits for various performance parameters, including gain, noise figure, linearity, and stability.

Wireless Communications:

ADS is widely used in the development of wireless communication systems, including cellular networks, WLAN, Bluetooth, and satellite communications. It allows engineers to analyze system-level performance, optimize signal paths, and evaluate modulation schemes.

High-speed digital design:

The software supports the design of high-speed digital systems such as data buses, memory interfaces, and serial links. It helps evaluate signal integrity, power distribution, and timing issues in complex digital designs.

Aerospace and Defense Electronics:

ADS is widely adopted in the aerospace and defense industries for the design and analysis of radar systems, electronic warfare equipment, satellite communications, and avionics. It aids in optimizing performance, minimizing

Chapter 5

DESIGN AND IMPLEMENTATION

The block diagram consists of Antenna, an Impedance Matching network, an RF-to-DC converter, and a DC-to-DC convertor. The antenna captures the transmitted radio frequency in the form of an AC signal and sends it to the RF-to-DC circuit, which is nothing but a rectifier circuit to convert the AC signal into a DC signal. The impedance-matching circuit is implemented such that it prevents signal reflection and inefficient power transfer. These reflections cause destructive interference, leading to peaks in the voltage. The DC-to-DC converter can be either be buck converter, boost converter, or a buck-boost converter which will be dependent on the input value of the device to which it will be fed. The antenna absorbs the emitted RF signal and feeds the AC signal to the rectifier circuit of AC-to-DC conversion which should be changed based on the need of

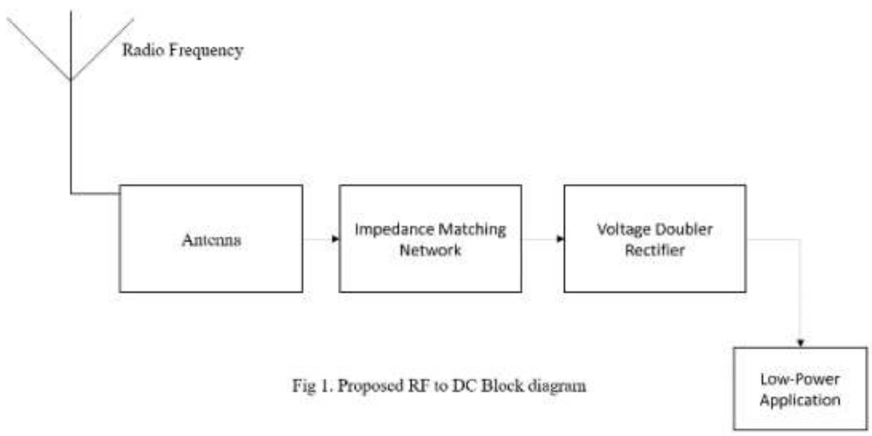


Fig 1. Proposed RF to DC Block diagram

5.1 Impedance Matching Network

In our design, the impedance matching network is an important part to ensure effective impedance matching between the microstrip patch antenna and the voltage doubler rectifier. It plays a key role in maximizing power transfer and minimizing signal reflections, thereby optimizing the energy-harvesting process of RF signals. The Impedance matching network is carefully designed and configured to bridge the impedance mismatch between the antenna and the rectifier. By choosing appropriate values for the inductance and capacitance in the network, we achieve an ideal impedance transformation that matches the impedance of the microstrip patch antenna. Through careful analysis and simulation using tools such as Keysight ADS, the Impedance matching network is tuned to operate efficiently at the

The resonant frequency of the antenna, which in our case is 94 MHz. This frequency alignment ensures optimal impedance matching and efficient power transfer.

The impedance transformation is given by the formula

$$Zin = \sqrt{Zout * Zant}$$

- Zin is the input impedance of the LC matching network.
- Zout is the output impedance of the LC matching network
- Zant is the impedance of the microstrip patch antenna at the resonant frequency.

An impedance transformation of approximately 50 ohms is determined in this circuit. This value corresponds to the output impedance of the network (Zout) and the impedance of the microstrip patch antenna (Zant) at its resonant frequency.

Fig 6.3. Represents impedance matching network, there are two microstrip lines in the circuit: MLIN and MLOC. MLIN is a microstrip line with a width of 1.122 mm and a length of 15.025 mm. MLOC is also a microstrip line with the same width of 1.122mm and a longer length of 22.490mm. Also, there is a 10pF capacitor in the circuit. Capacitors are used to provide the required capacitance to a circuit and to help with impedance matching or filtering requirements depending on the particular design environment. These specific dimensions and component values play a critical role in circuit performance and function, contributing to impedance transformation, signal propagation, and other desired characteristics.

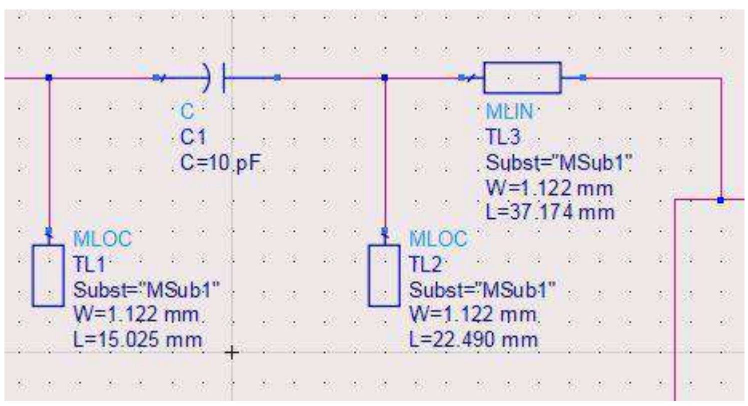


Figure 5.1

5.2 Voltage doubler Rectifier

A voltage doubler rectifier is a circuit configuration commonly used in power harvesting applications to convert an RF signal into usable DC power. It is based on the principle of rectifying and multiplying the input voltage using diodes and capacitors. Here is Fig 5.2. Represents the proposed Voltage doubler rectifier It consists of two diodes and one capacitor arranged in a particular way. During the positive half-cycle of the input AC signal, one of the diodes conducts current and charges the capacitor. During the negative half cycle, the other diode conducts, and the previously charged capacitor discharges through the load resistor.

This arrangement effectively doubles the voltage across the load resistor. The circuit's voltage doubler rectifier uses HSMS 2868 diodes and 150 pF capacitors. The microstrip line MLIN has a width of 1.122 mm, while the corresponding MLOC has the same width. The length of the MLOC is 19.189 mm.

The load resistance connected to the voltage doubler rectifier is 330 ohms. To measure the performance of the circuit, an I_PROBE, and a P_probe are connected, both with an impedance of 50 ohms. Using HSMS 2868 diodes and capacitors, the voltage doubler rectifier circuit rectifies the AC input signal, effectively doubling the voltage across the load resistor. The specific dimensions and component values of the microstrip lines, diodes, capacitors, and load resistors are carefully chosen to optimize power transfer and circuit performance.

The I_PROBE and P_PROBE connected to a 50Ohm impedance allow precise measurement and analysis of the behavior of the circuit and ensure accurate evaluation of the efficiency and voltage doubling capability of the voltage doubler rectifier.

In the following sections, we present the integration of the individual blocks, including the impedance matching network, and voltage doubler rectifier, and their respective simulations. All the simulations and analysis are done in the Keysight ADS tool and the parameters of all individual circuits are documented and analyzed in this paper. In Figure 5.3, we present a comprehensive block showing the integration of all individual circuits, namely the impedance-matching network, and voltage doubler rectifier. The diagram provides a visual representation of the combined system and illustrates the connections and relationships between the various components.

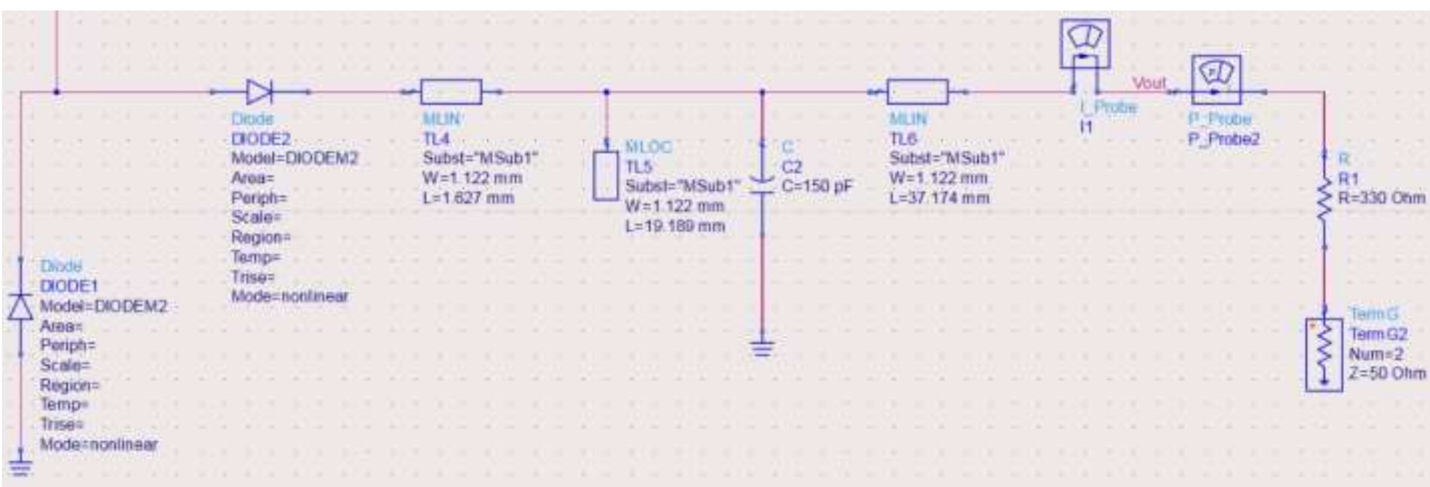


Figure 5.2

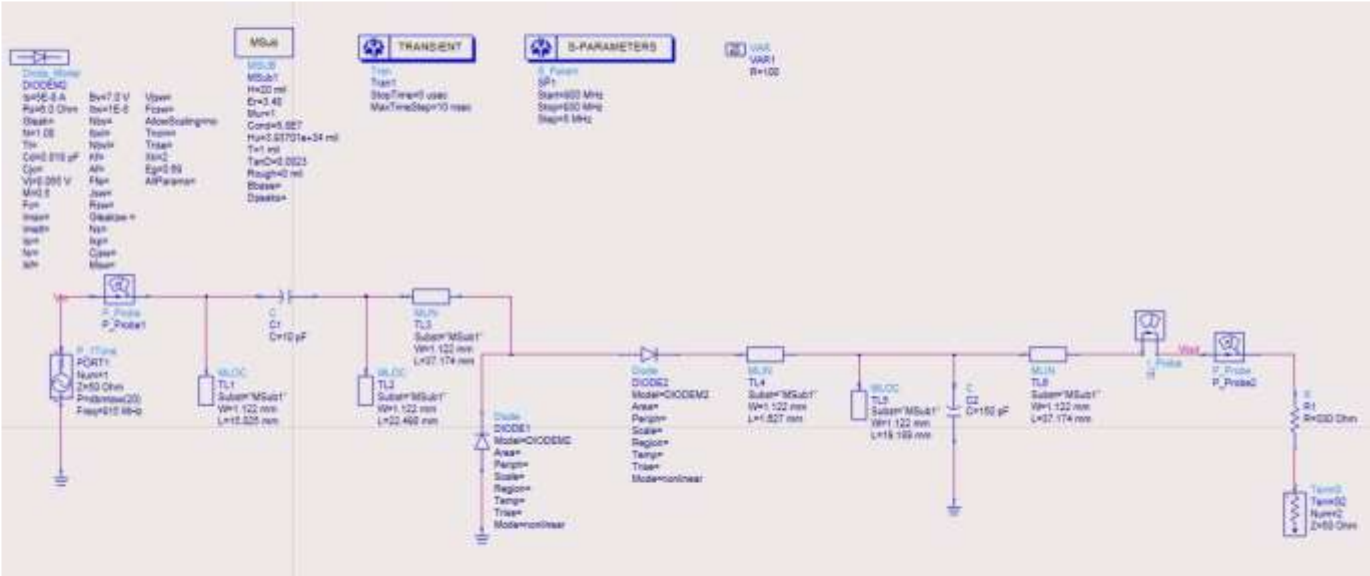


Figure 5.3

5.3 Microstrip Patch Antenna

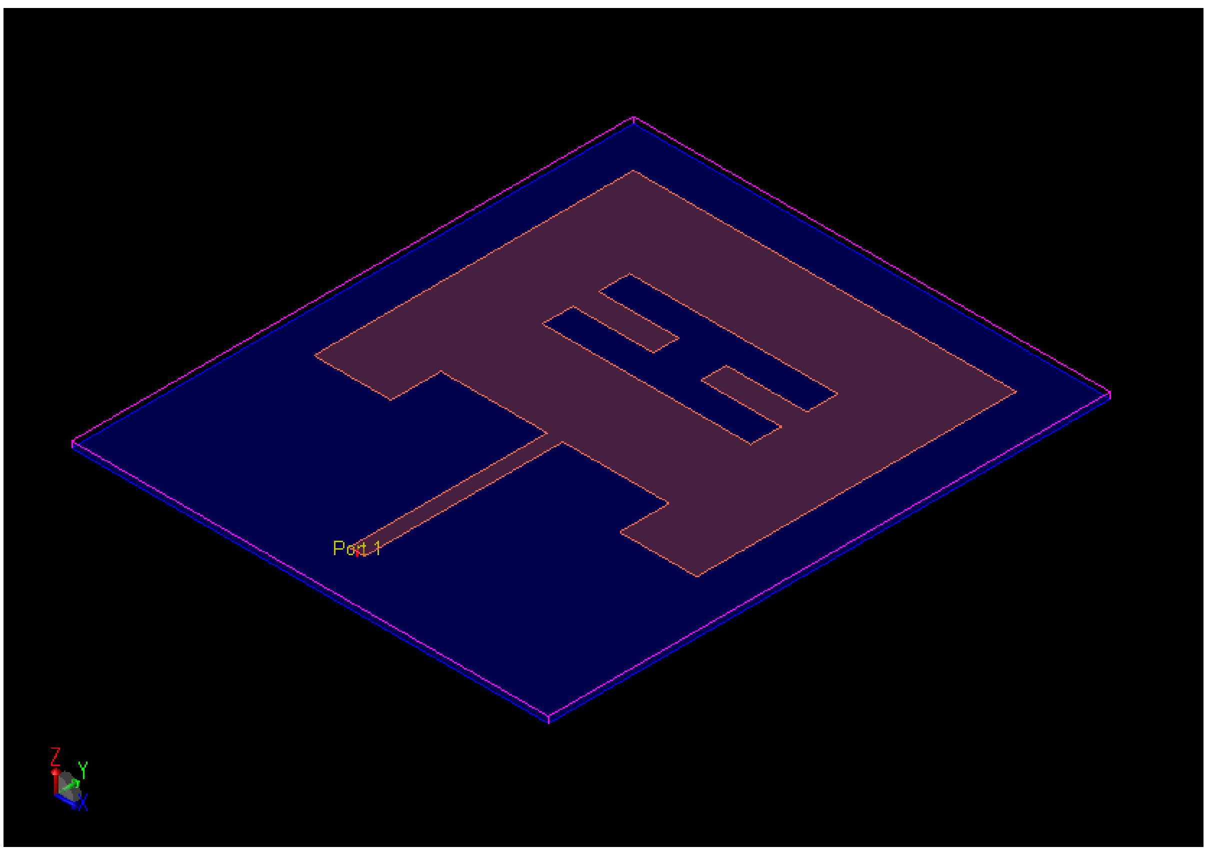


Figure 5.4

A microstrip patch antenna was constructed with a width of 99.18mm and a height of 82.945mm, an I-shaped space was introduced in the patch antenna to increase the output efficiency of the antenna. The power to the antenna is provided through Port1 as shown in Fig5.4. For the substrate, Alumina is the dielectric with a permittivity (Er) of 9.6 and a dielectric loss tangent (tan ρ) of 0.025. The thickness of the substrate was chosen to be 1.6mm. The conductor was chosen based on considering its cost and efficiency and the conductor used for the transmission of the signal is copper with a thickness of 0.35mm as shown in Fig 5.5.

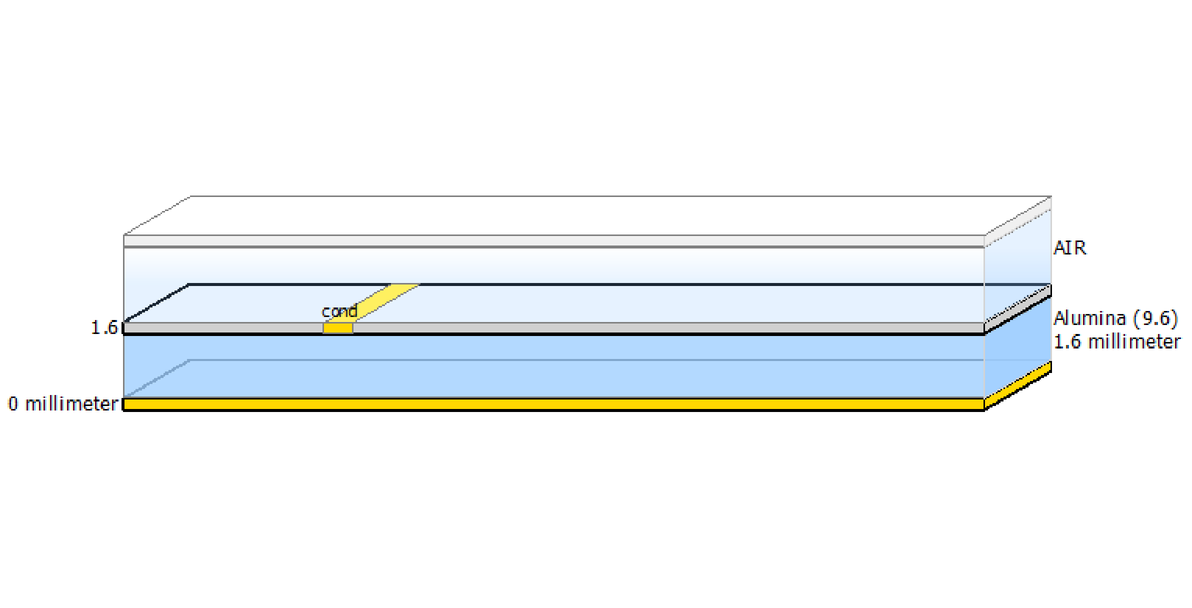


Figure 5.5

Chapter 6

EXPERIMENTAL RESULTS & DISCUSSION

6.1 Microstrip Patch Antenna

Our proposed microstrip antenna for the patch is constructed using the Keysight ADS software. The antenna employs an Alumina substrate with a dielectric constant of 9.6. It's intended to oscillate at a frequency of 940MHz. The substance conducting electricity is copper. The width and height of the antenna are 99.18mm and 82.945mm respectively.

Through simulation and analysis in Keysight ADS, the proposed antenna has an effective angle of 3.828 degrees, a radiation intensity of 60%, and a gain of 2.9 dB. These values are achieved when the antenna is powered up to 17 dB input power.

The design of this microstrip patch antenna takes into consideration the properties of the substrate and its dimensions, it is intended to maximize its capacity for radiation and gain. The utilization of Keysight ADS promotes accurate modeling and optimization, which results in a successful proposal for an antenna design with a dependable outcome. Fig 6.1. Represents the proposed microstrip patch antenna and Fig 6.2. represents the various antenna parameters.

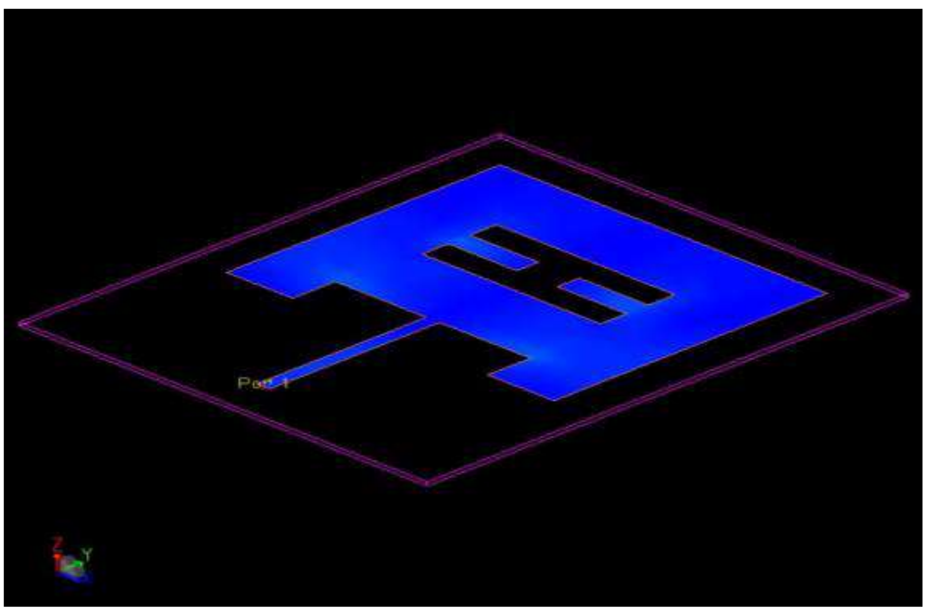
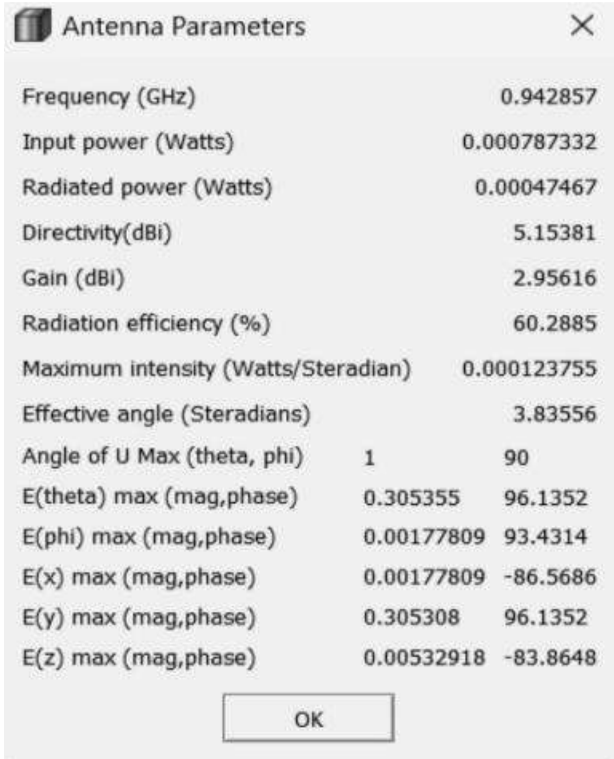


Figure 6.1



Antenna Parameters

Frequency (GHz)		0.942857
Input power (Watts)		0.000787332
Radiated power (Watts)		0.00047467
Directivity(dBi)		5.15381
Gain (dBi)		2.95616
Radiation efficiency (%)		60.2885
Maximum intensity (Watts/Steradian)		0.000123755
Effective angle (Steradians)		3.83556
Angle of U Max (theta, phi)	1	90
E(theta) max (mag,phase)	0.305355	96.1352
E(phi) max (mag,phase)	0.00177809	93.4314
E(x) max (mag,phase)	0.00177809	-86.5686
E(y) max (mag,phase)	0.305308	96.1352
E(z) max (mag,phase)	0.00532918	-83.8648

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Figure 6.2

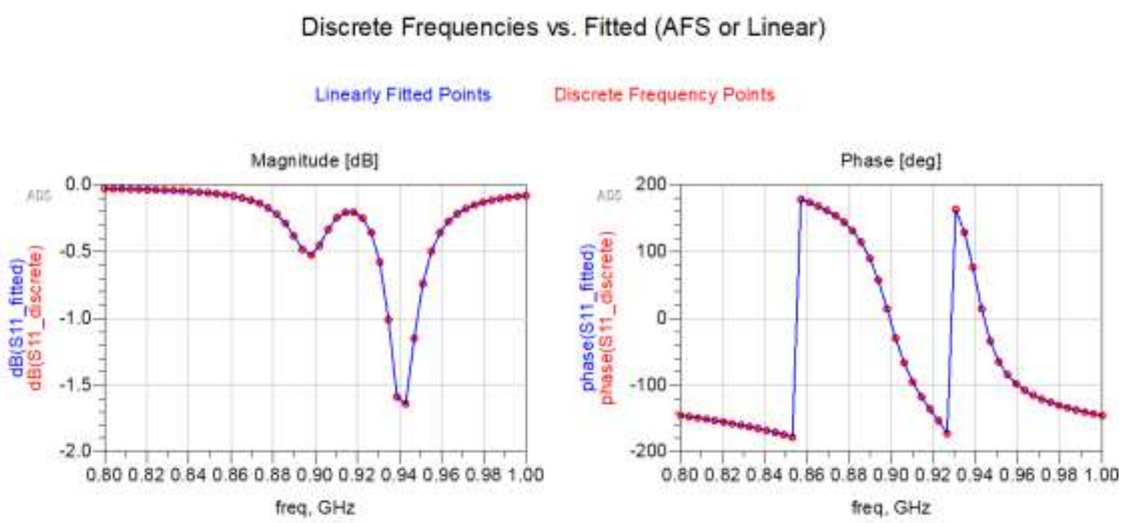

Figure 6.3

Examining the radiation pattern, we find that the antenna exhibits its maximum radiation intensity at a vertical angle of 79 degrees (Theta max) and a horizontal angle of 180 degrees (Phi max). The simulation also reveals the directivity max value of 6.015, which implies that the antenna can concentrate its radiated power in a specific direction. This characteristic allows for enhanced signal strength and coverage in desired areas. Moreover, the maximum gain (Gain max) is determined to be 2.95 dB, reflecting the antenna's ability to amplify and direct the radiated energy. In terms of radiated power, the simulation yields a value of 1.764E-3 milliwatts, quantifying the strength of the signals emitted by the antenna. This parameter is critical for assessing the overall performance and signal transmission capability of the antenna. The efficiency is found to be 60.2%, the simulation output specifies the radiation pattern cut type as "Phi" (horizontal plane) with a cut angle of 0 degrees. This information makes it possible to analyze the antenna's radiation pattern within a specific plane and angle, aiding in the optimization of the antenna's design for desired signal coverage. All the obtained outputs from the antenna simulation are shown in Fig 6.4.

Frequency	E_max	Theta_max	Phi_max	Directivity_max	Gain_max	RadiatedPower	InputPower	Efficiency	CutType	CutAngle
8.000E8	0.021	79.000	180.000	6.015	-3.893	1.764E-6	1.727E-5	0.102	Phi	0.000

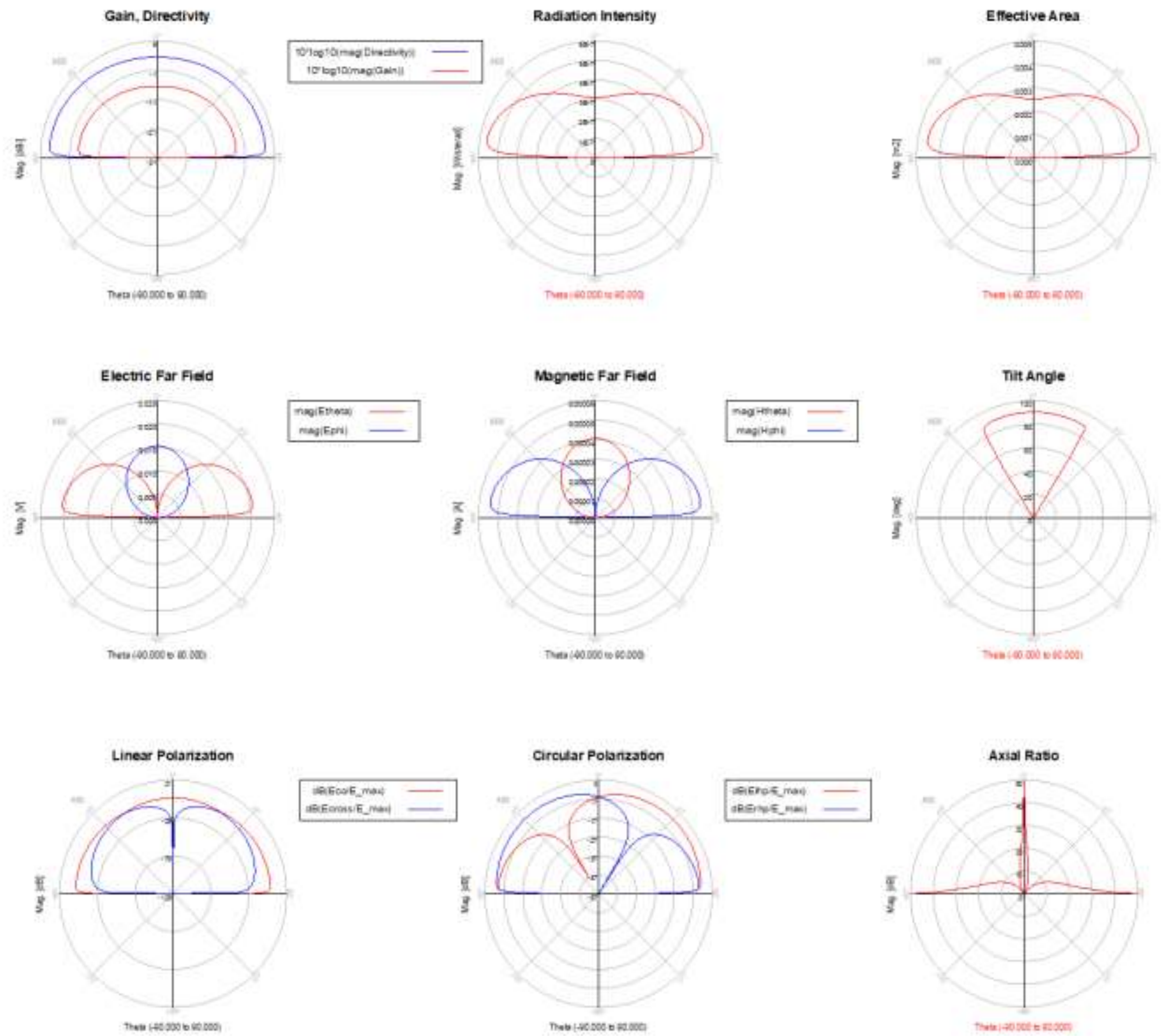

Figure 6.4

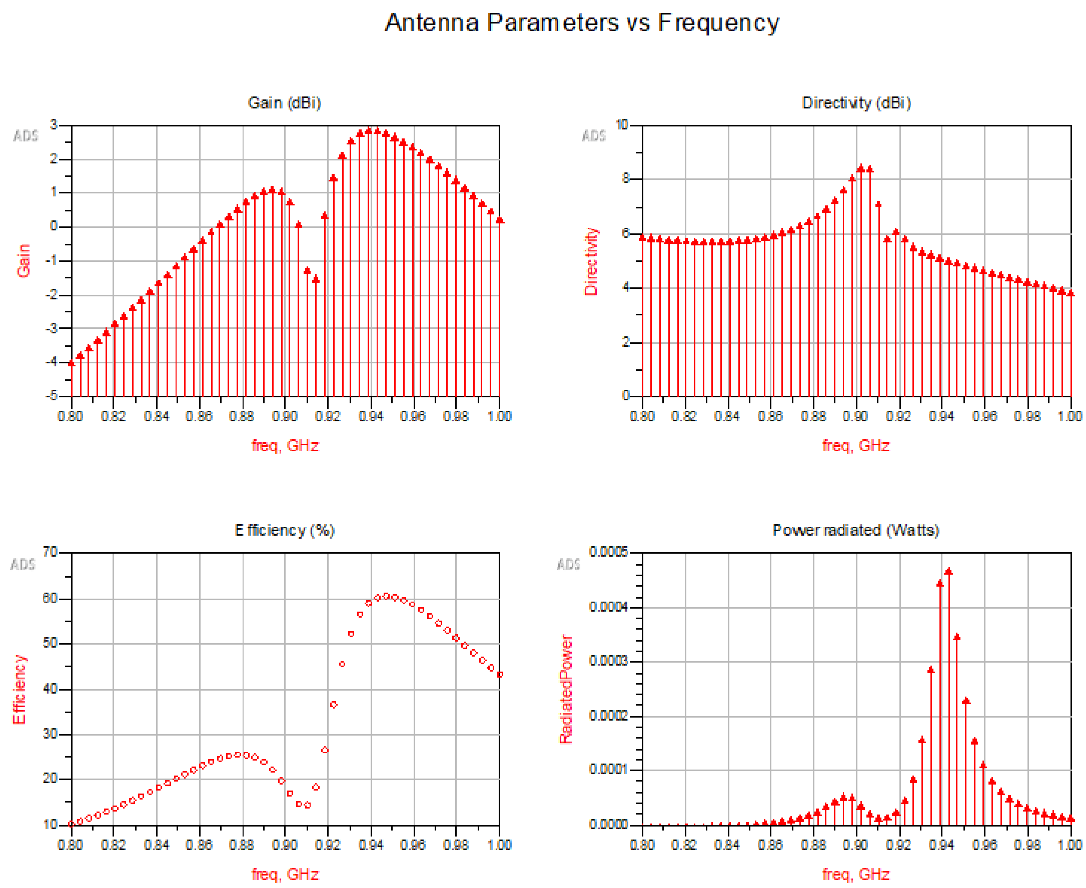

Figure 6.5

6.2 RF-to-DC Simulation

The simulation of the RF-to-DC converter was carried out using Keysight ADS, a robust software tool widely used for electronic design and simulation. The main objective was to achieve a stable DC output voltage of 2.305 V and a current of 6 mA. To ensure accurate results, the circuit design was thoughtfully crafted, taking into account the specific requirements. Careful consideration was given to selecting suitable components and configuring their parameters to meet the desired specifications. The simulation in Keysight ADS accurately models the behavior of the circuit components, accounting for various factors such as their individual characteristics, signal frequencies, and impedance matching. Throughout the simulation process, the performance of the RF-to-DC converter was closely monitored. Special attention was given to observing the stability and consistency of the output voltage and current, which were critical in meeting the desired specifications. Fortunately, the simulation yielded positive results. A stable DC output voltage of 2.305 V was achieved (as shown in Fig 6.6.), demonstrating the successful conversion of RF signals into a reliable and constant voltage level. Additionally, the measured output current was 6 mA (as shown in Fig 6.7.), signifying the flow of current within the circuit. These results hold great significance as a stable DC output voltage and current are essential for ensuring consistent power supply in a wide range of applications. By conducting the simulation in Keysight ADS and achieving the desired output parameters, confidence is gained in the circuit's design and its practical implementation. The simulation outcomes serve as a validation of the circuit's functionality and provide valuable insights for potential refinements or customization, should the need arise.

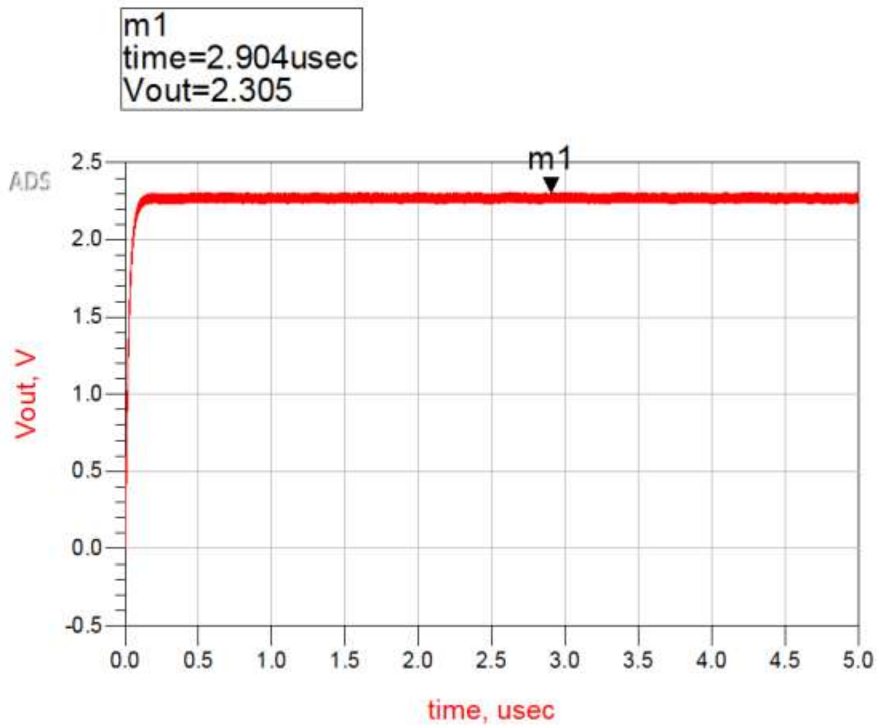

Figure 6.6

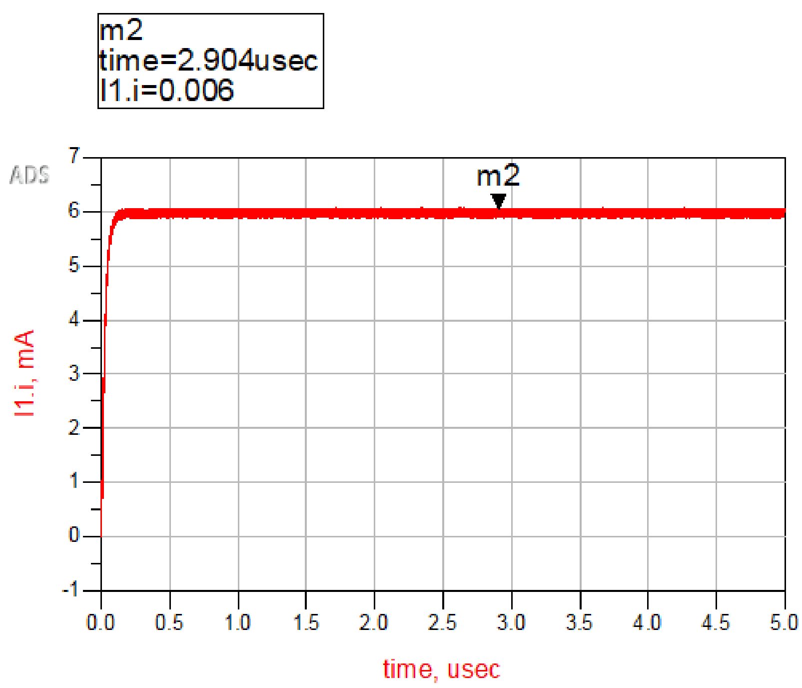

Figure 6.7

Chapter 7

CONCLUSION

In conclusion, the simulation results of the RF-to-DC converter using Keysight ADS have been promising and have achieved the desired outcomes. The obtained stable DC output voltage of 2.305 V and current of 6 mA validate the effectiveness of the circuit design and the accuracy of the simulation software. These results showcase the converter's capability to efficiently convert RF signals into a reliable DC voltage, ensuring a consistent power supply for a wide range of applications. The insights gained from the simulation provide valuable information for further

7.1 Future Enhancement

The future development of this technology is vast as an improved antenna with different substrates, sizes, and shapes can be introduced for much greater efficiency. The antenna can be made much smaller for implementation in on-chip devices reducing the size of the device and implementing more components on the device. The improvement in antenna can result in greater range and higher power transfer such that more power can be transferred for various uses like infrastructure and industrial machinery. The increased scalability can result in the running of multiple devices by the use of a single source which can lead to less power consumption and efficient usage of the device.

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