MINI PROJECT REPORT (EC 65)

Dept. of Electronics and Communication Engineering

Report submitted for the project

DESIGN OF DUAL BAND ANTENNA FOR IMPLANTABLE APPLICATIONS

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CERTIFICATE

This is to certify that the Mini Project work entitled as the topic "**Design of Dual Band Antenna for Implantable Applications**" is carried out by **Rahul Kumar Singh (1MS20EC073), Rahul Sundriyal (1MS20EC074), Vishwaraj HR (1MS20EC129), Vishwas Uniyal (1MS20EC130)**, bonafide students of Ramaiah Institute of Technology, Bangalore, in **Electronics and Communication** of the Visvesvaraya Technological University, Belgaum, during the year 2022-2023. It is certified that all corrections / suggestions indicated indicated for Internal Assesment have been incorporated in the report.

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Assistant Professor	Professor and HOD
Department E&C	Department of E&C
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Name and signature of examiner with date

1.

2.

DECLARATION

We hereby declare that the Mini Project entitled " Design of Dual Band Antenna for Implantable Applications" has been carried out independently at Ramaiah Institute of Technology under the guidance of **Dr. S. Imaculate Rosaline, Assistant Professor, Department of Electronics and Communication, RIT Bangalore**

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ABSTRACT

The increasing demand for the implantable medical devices has necessitated the development of efficient and reliable antenna systems that can operate within the limited space and stringent constraints of the human body. This project focuses on the design and optimization of a **dual-band antenna** suitable for implantable applications, with the objective of achieving reliable wireless communication in both the **Medical Implant Communication Service (MICS) and the Industrial, Scientific, and Medical (ISM) band.**

To achieve this, extensive research and analysis were conducted on antenna design principles, implantable applications, and regulatory requirements. The antenna design process involved utilizing advanced **electromagnetic simulation** tools and optimization techniques to ensure optimal performance and compliance with relevant safety regulations.

Key design considerations included miniaturization, efficiency, radiation pattern, and impedance matching. The key design also addressed the challenges posed by the human's body's electromagnetic environment, such as tissue absorption, reflection, and interference. Special attention were given in minimizing tissue absorption and ensuring the antenna's compatibility with the human body.

CONTENTS

MOTIVATION

The motivation behind this project stems from the need to address the challenges posed by **implantable devices' communication systems**. Traditional antenna used in external wireless devices are often unsuitable for implantable applications due to several factors, including limited space within the body, electromagnetic absorption by tissues, and strict regulatory requirements for safety and compatibility.

The **dual band system** aims to overcome these challenges by providing a compact, efficient, and reliable solution for wireless communication in implantable medical devices. The system will operate within **ISM bands**, which will result in it's high versatility.

Implantable devices have the potential to significantly improve patient care, enabling real-time monitoring, personalized treatment, and timely intervention. By designing a **dual-band antenna** optimized for implantable applications, this project contributes to the advancement of wireless communication within the human body, ultimately enhancing the functionality and effectiveness of implantable medical devices.

INTRODUCTION

An **implantable medical device** is a device that is designed to be inserted into the body of monitoring or treating a medical condition. Examples of implantable devices include pacemakers, neurostimulators, and insulin pumps. These devices require a power source, which is typically a battery. However, replacing the battery when it runs out can be difficult, particularly for devices that are implanted in hard-to-reach cases.

To address this challenge, researchers have explored the use of **wireless energy transfer** for implantable devices using electromagnetic waves to transfer energy from a transmitter to a receiver without any physical contact having the potential to eliminate the need for batteries in implantable devices.

One key component of wireless energy transfer system is the rectenna which is a device that combines a rectifier and an antenna to convert electromagnetic waves into DC power. In the context of implantable devices, a **dual-band rectenna** is designed to operate at two different frequencies. It has the potential to improve the efficiency and reliability of wireless power transfer to implantable devices, as they can be designed to operate at frequencies that are less affected by tissue absorption and interference.

Overall the design of **Dual-Band rectenna** for implantable applications is an important area of research tha has the potential to improve the performance of wireless energy transfer systems for powering implantable medical devices.

PROBLEM STATEMENT

The project aims to develop a **Dual-Band** miniaturized rectenna for **implantable applications** with proper impedance matching techniques operating in a suitable frequency.

Implantable medical devices have transformed healthcare by providing continuous monitoring of vital signs, targeted drug delivery, and improving the quality of life for patients with chronic conditions. However there are several challenges associated with implantable devices, including the need for reliable power sources, the risk of infection, and the potential for device failure.In this report we explore the need for implantable devices and the potential solutions that can be developed to address these challenges.

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PROJECT OBJECTIVE

- Improve Power Efficiency **-** One of the primary objectives of **dual band rectenna** based implantable applications is to improve the power efficiency of the implantable device by designing a **rectenna** that is optimized for the frequency of the electromagnetic waves being used for wireless energy transfer.
- Increase Reliability - Another objective is to increase the reliability of the wireless power transfer system by designing a **dual band rectenna** that can switch between frequencies in response to changes int the environment ensuring **consistent power supply.**
- Reduced Device Size - **Dual band rectennas** can be designed to be smaller and more compact than traditional rectennas, which can reduce the size of the implantable device. This is particularly important for devices that need to be implanted in **hard-to-reach** areas of the body.

LITERATURE SURVEY

[1] Priya Sharma, Ashutosh Kumar Singh. A survey on RF energy harvesting techniques for lifetime enhancement of wireless sensor networks. Department of Electronics and Communication Engineering, Indian Institute of Information Technology Allahabad. Volume 37. January 2023.

- This paper discussed about various sources of energy harvesting techniques. Ambient RF energy has been harvested from mobile phone network signals and Wi-Fi signals in urban areas to power a wide range of low poer devices via wireless charging.

- A rectifier circuit is used to convert received RF power into DC power. A wide dynamic range of rectifiers is embedded in rectifying circuits for RF energy harvesting for low power devices such as WSNs, which uses ambient RF energy sources as input.

- The average low input RF power received by an antenna is -25dB. In general, a typical p-n junction diode cannot operate in such environment because of it’s high threshold voltage.

- For an energy harvesting system, we need very low cut-in voltage to operate the circuit with high switching speed and RF components which operate in high frequencies.

- According to their requirements in the applications, different characteristics of microwave Schottky diodes have been used such as HSMS2852, HSMS2822, HSMS285 C, etc.

- A circular microstrip patch antenna has been designed using fractal geometry based on Koch curves with the seond number of iterations, operating at a center frequency of 2.45 GHz. The design increases the power length of the antenna by creating additional iterations, resulting in a surface current at the boundary of the radiating surface.

- In order to achieve high efficiency, multiband and broadband antennas have been created to receive more energy in the frequency band.

[5] Adel Khemar, Abdellah Kacha, Hakim Takhedmit, Ghalid Abib, Design and experiments of a dual-band rectenna for ambient RF energy harvesting in urban environments, September 2017, Departments of Electronics, Faculty of Science and Technology, University de Jilel, 18000, Algeria

- Energy harvesting technologies are required for autonomous applications, like sensors, for which a long-time power sourcing from battery is infeasible. An energy harvester converts different forms of environmental energy into electricity.

- It can replace, totally or partially, the batteries of certain micro-systems that have low-energy requirements. Therefore, the authors exploit the use of electromagnetic waves from broadcasters to power wireless sensors.

- The authors propose to realize harvesting operation at typical ambient radio frequency power levels found within urban environments. To explore the potential from ambient RF energy harvesting, an RF spectral survey was undertaken from outside in Paris.

- The average RF power in the frequency range 0.9-3 GHz is about -12dBm. The harvester includes an antenna, an impedance-matching network, and a rectifier; it was designed to cover two frequency bands from the largest RF contributors (GSM 1800 and UMTS Band 1). A DC power ar presented.

- An efficiency of ~45% was observed experimentally for the UMTS Band 1 and 33% for the GSM1800, whenever the incident power is -7dBm.

[4] Islam Mansour, Maarwa Mansour, Mohammad Aboualalaa, Compact and Efficient Wideband rectifier based on pi-network with wide input ppower ranges for energy harvesting, Electrical Engineering Department, Shoubra Faculty of Engineering, Benha University, Cairo 11629 Egypt, Version of Record, 31st, December 2022.

- This work introduces a wideband, significant RF_DC conversion efficiency and large DC voltage radio frequency (RF) voltage multiplier/doubler rectifier for energy harvesting (EH) systems utilizing ROG4003C material and Schottky diode.The iput matching network is designed using pi-network and series reonanace circuit.

- Two wideband rectifiers are designed that first one uses lumped inductors in the pi-network, and the second design employs distributed rectangular inductors. The pi-network is connected in series with a Schottky diode to compensate its capacitive reactance, diminish its impedance variation when the frequency or inout power varies while the series resonance circuit is used to match the minimized variance to the source impedance .

- An HSMS2852-based rectifier prototype is tested for verification, obtaining a bandwidth of 31.6% from 720 to 1050 MHz with 68+- 2 % at an input power of 3dBm with a peak saturated DC voltage of 3.6V and an input return loss (S11) less than -10dBm and 5dBm via various load terminals ranging from 2.5KOhms to 10KOhms.

- The proposed rectifier is suitable for GSM 900, IOT, UHF ISM 900 MHz, WSN, broadband LTE, and multi-standard systems. Finally, the introduced voltage doublers have a compacted area equal to 1.85cm2.

[2] P.K. Singhal, Vandana Vikas Thakare, Shailendra Singh Ojha. Dual Band rectenna system for biomedical wireless application. Department of Electronics, Madhav institute of Technology and Science Gwalior. Volume 24. December 2022. 100532. Publisher-Elseiver.

- This paper propsed a dual band RF Energy harvester to power Biomedical wireless device for various health applications. Biomedical devices may be implantable devices or wearable devices.

- The propsed system's novelty is that it can work in widespread operating frequency range with good efficiencies.

- This paper is based on studies done in various countries that indicate that GSM 900 MHz and 1800 MHz are most capable bands for wireless power harvesting. It uses single Schottky Diode rectifier which works well for the proposed GSM band. It was optimised for low input power conditions which has a benefit of delivering high output voltage, condensed size and low cost.

- It also proposed a dual feedline antenna having return loss of -24dB at 900MHz and -34dB at 1800MHz which makes it much better than a single feedline antenna having return loss of -19dB at 900MHz and -24dB at 900MHz.

- .Rectennas are identified as a critical component in far-field wireless energy transmission applications, converting RF-to-DC conversion efficiency for small input power variations are alo mentioned.

- The rectenna system without matching achieved efficiency of 33% and 35% at 900 MHz and 1800MHz but with the help of matching network the efficiency inreased to 52% and 78% at 1800MHz and 900MHz.

- The propsed antenna uses an FR-4 lossy substrate and has achieved over 50% conversion efficiency(capable of 78%) for input power variation of -8.5 to 10 dBm.

[3] Shamil H. Hussein, Khalid K. Mohammad. A miniaturised advanced rectenna integrated circuit for implantable applications. Department of Electrical Engineering, University of Mosul, Iraq, Volume 161, Marcf 2023, 154544

- This paper dicussed about the circuit consisting of compact FDA antenna, matching circuit, VDR circuit, and load. The best matching between the input impedance of the FDA antenna and rectifying circuit was achieved by making the real part of both devices similar and the imaginary part cancelled at specific frequency.

- It proposed a pi-network impedance matching ad series network circuit.

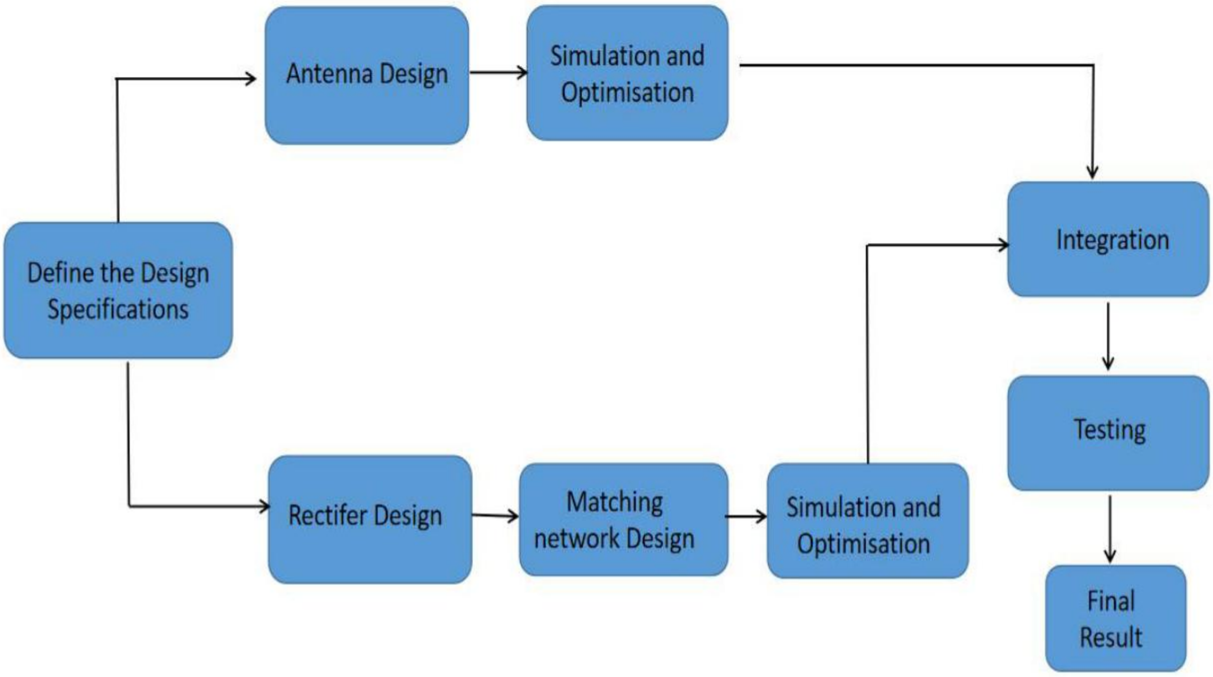
- Voltage doubler rectifier is shown using a output capacitor connected for energy storage along with the Schottky diode.

- The pi-network is connected in series with the Schottky diode to copensate its capacitive reactance, diminish its impedance variation when the frequency or input power varies while the series resonance circuit is used to match the minimised variance to the source impedance.

- By inserting two inductors the operational frequency of voltage doubler rectier is widened.

- The rectifier is suitable for GSM-900, IoT, UHF ISM 900 MHz, WSN, broadband LTE, and multi standard systems.

METHODOLOGY



- **Design Specifications**- The proposed circuit of the rectifier has been designed to operate within a frequency range of 900MHz to 1800MHz taking help of GSM bands and also being compatible with human body. Further making it suitable miniaturized version.

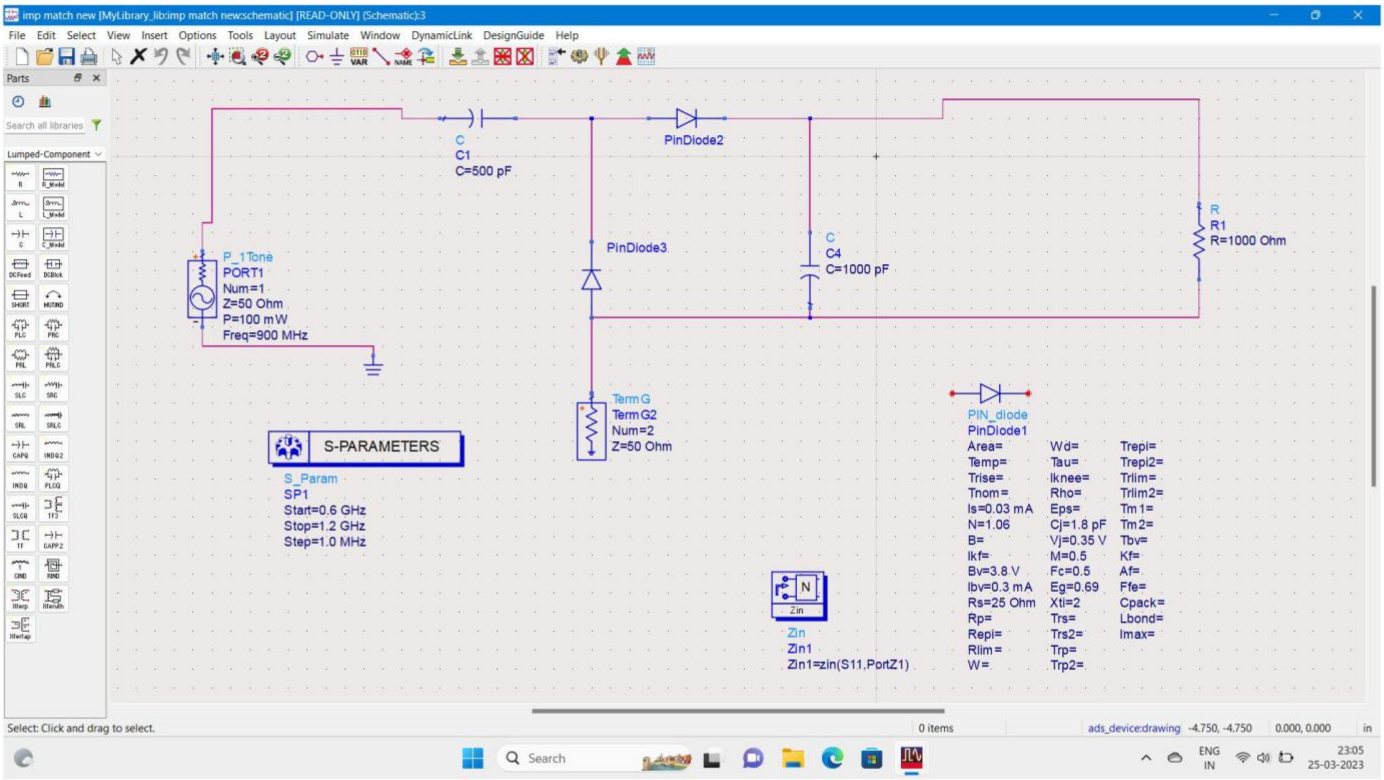
- **Matching Network-** This rectifier circuit went through the series of pi-matching network, T-matching network and ultimately L-matching network. These stages were the stages of improvement of the rectifier circuit.

- **Simulation**- After being made a suitable matching network some optimizations in the network has been done in order to make the circuit much efficient. The optimizations were done by setting the values for capacitance, resistances, voltage values etc.

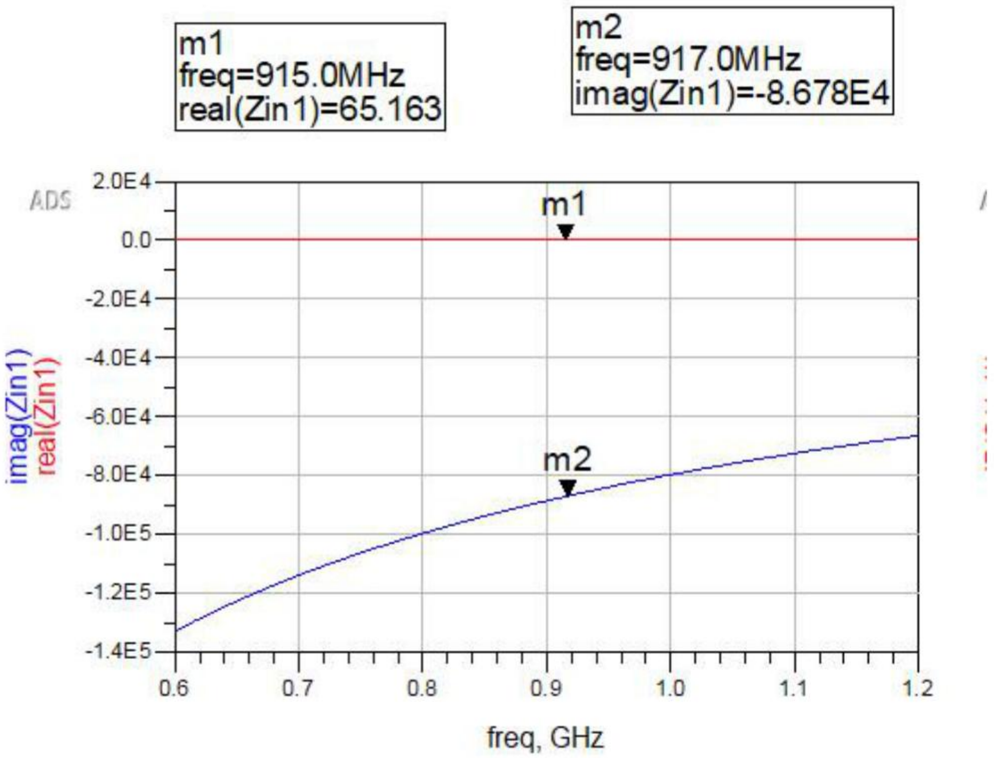
- **Testing**- After the circuits were made it has been tested under different configurations of resistances and capacitances along with the diodes

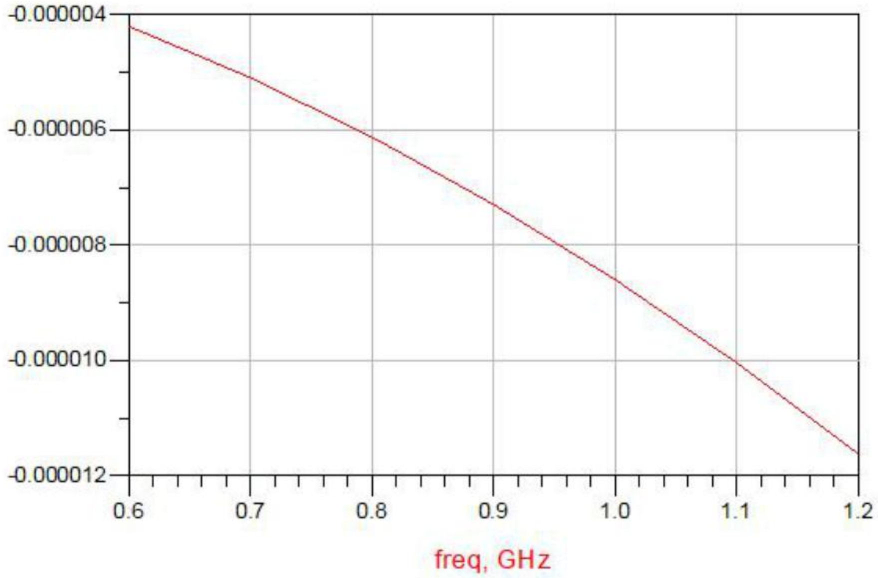
Proposed Work :- Circuit Design

Rectifier Circuit Without Matching Network

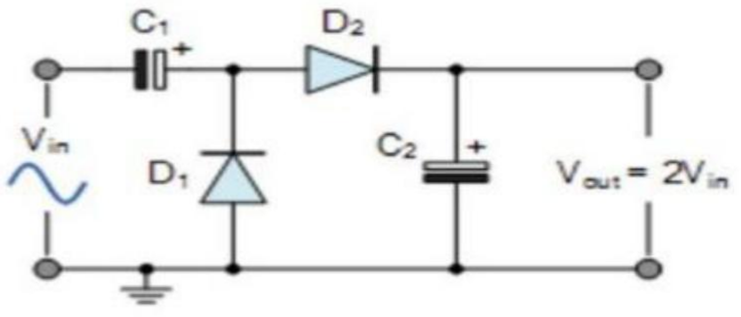


Output graph of the circuit



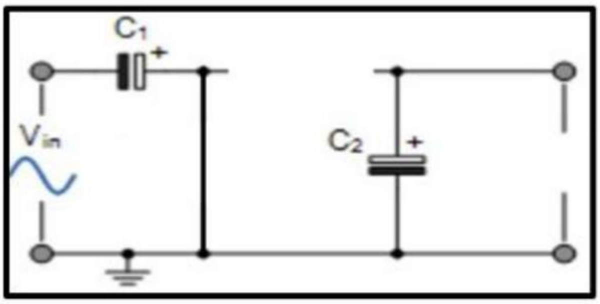


Voltage Doubler Configuration

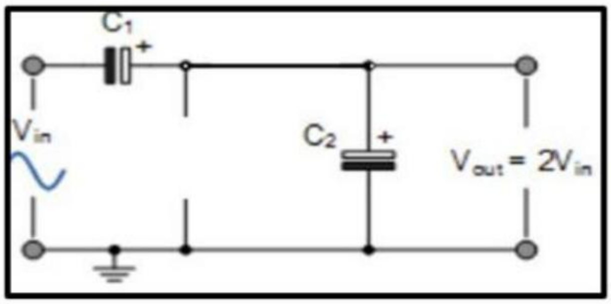


Rectifier Circuit with Voltage Doubler Configuration can help us to amplify the output voltage for better results.

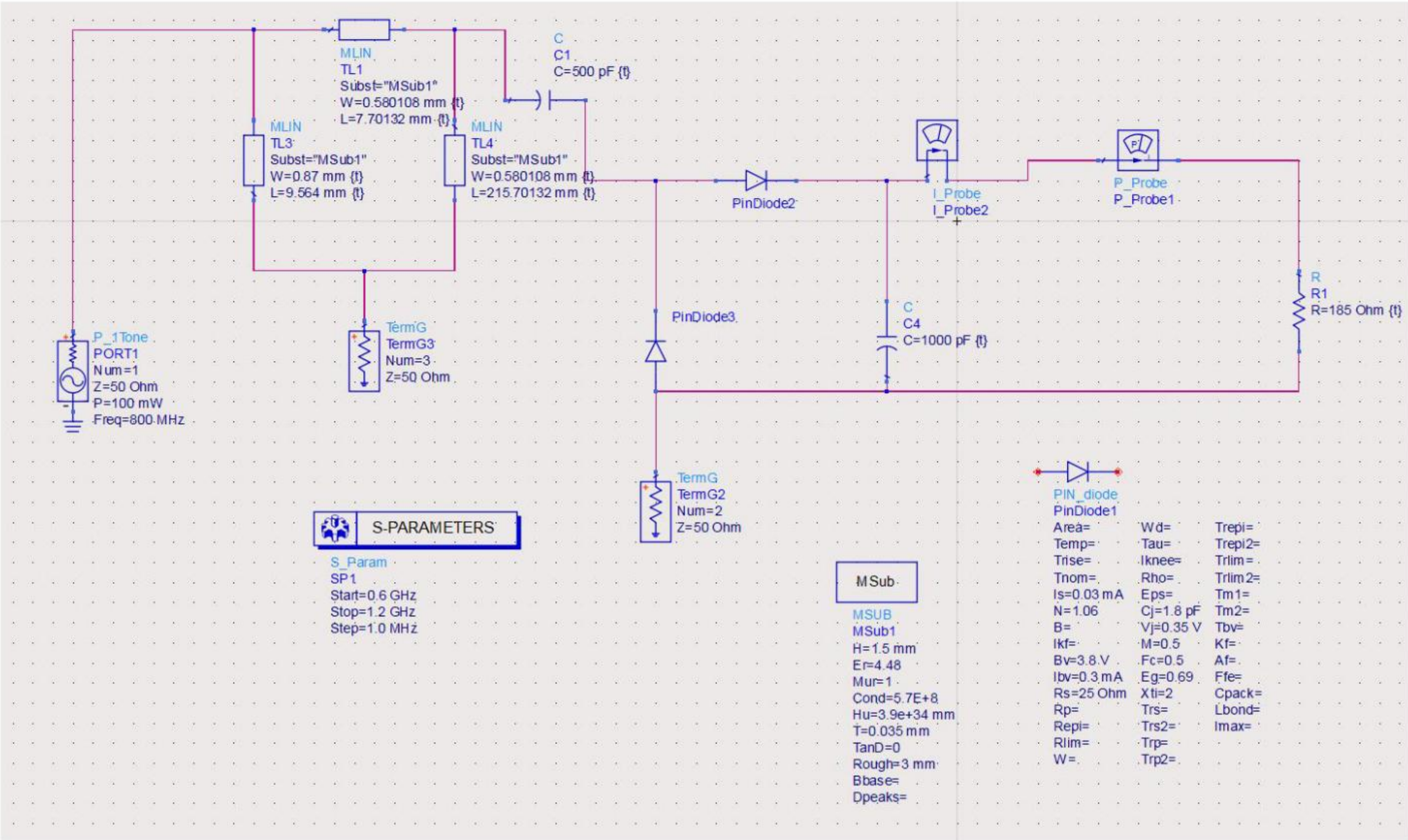
Negative Half Cycle:

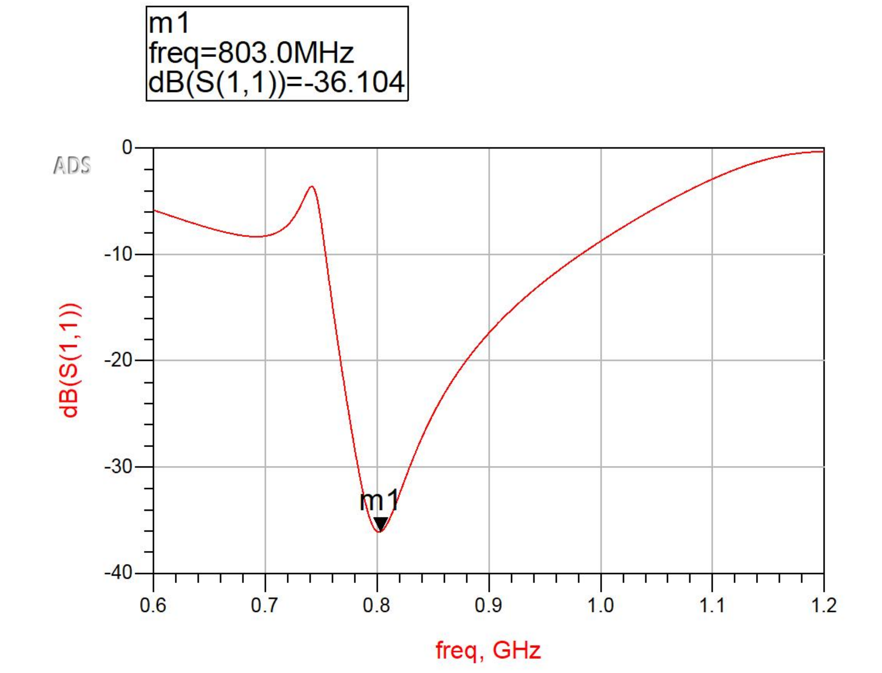


Positive Half Cycle:

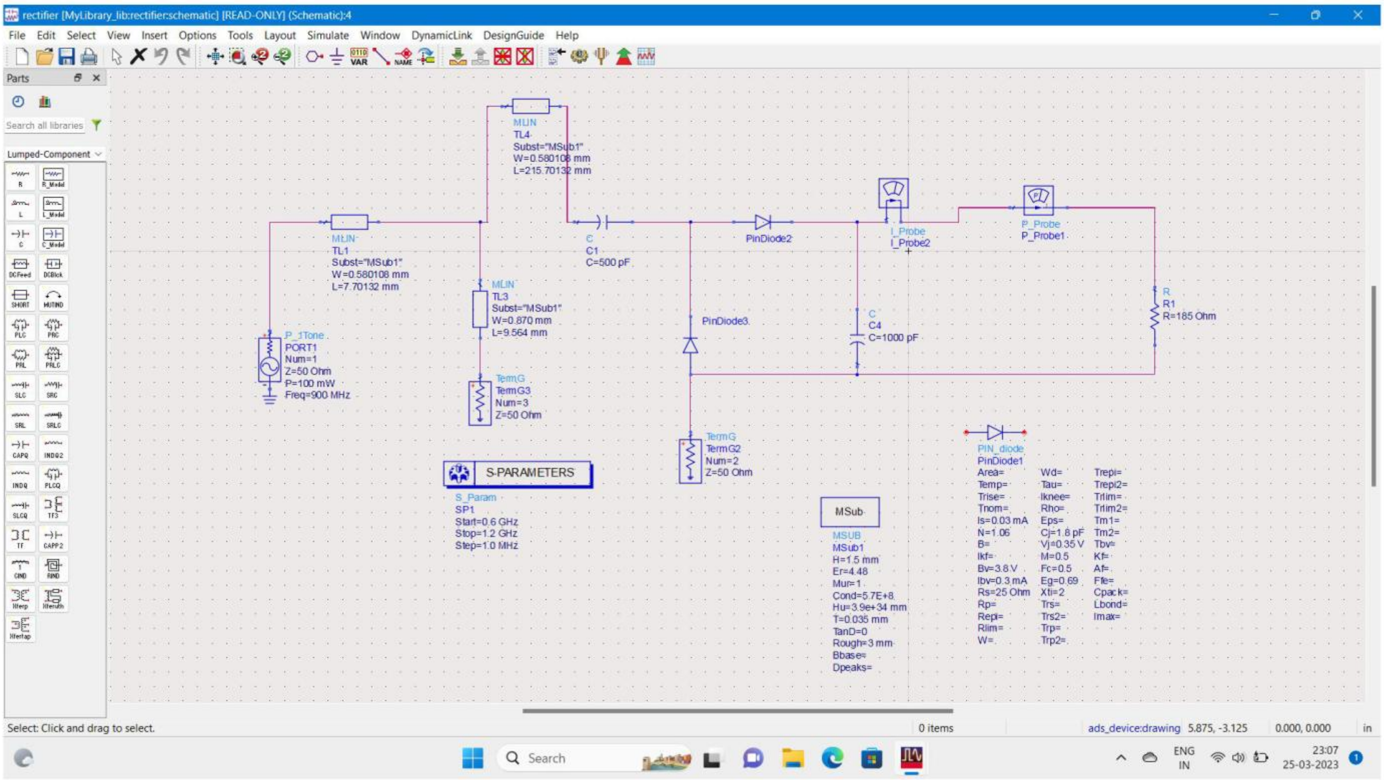


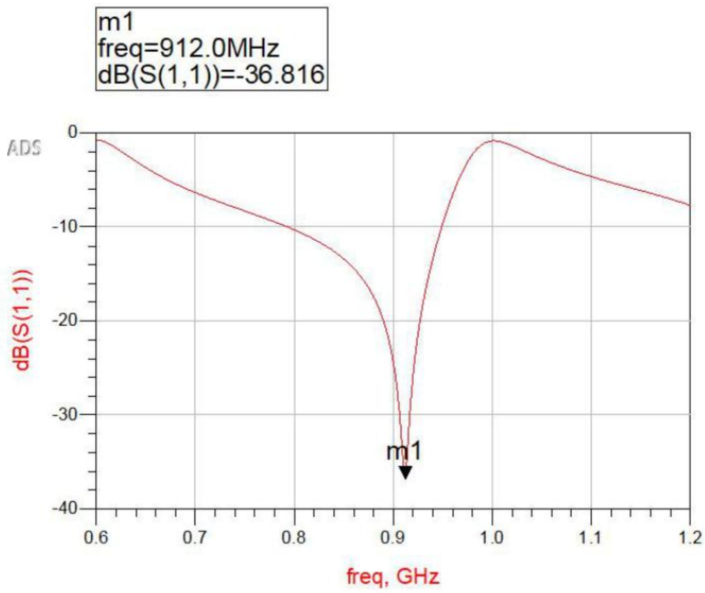
Rectifier Circuit with Pi-impedance matching network and Voltage Doubler Circuit:





Rectifier Circuit with T-Stub Matching and Voltage Doubler Configuration





Results and Discussions:-

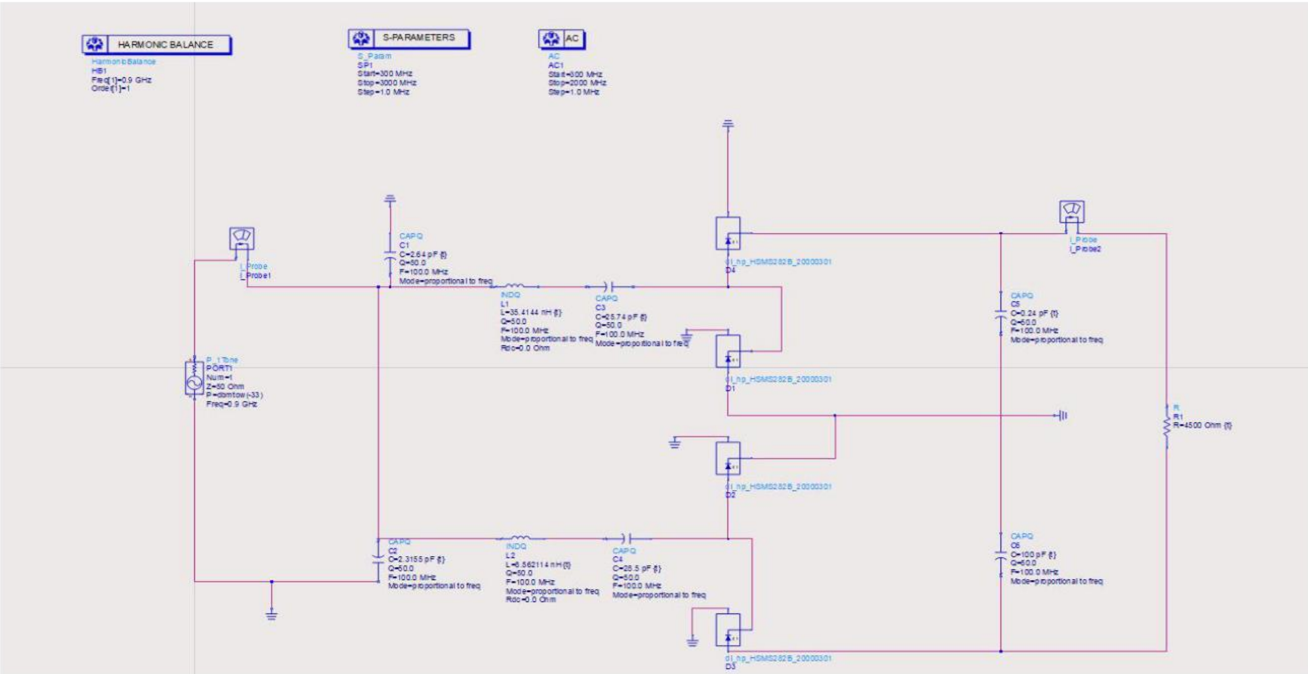
- For the above pi-impedance matching circuit we can see that the output graph is not ideal, inspite of tuning the circuit the S-parameter is resonating at 800 MHz which is not an ideal case as we have given a frequency of 900 MHz.

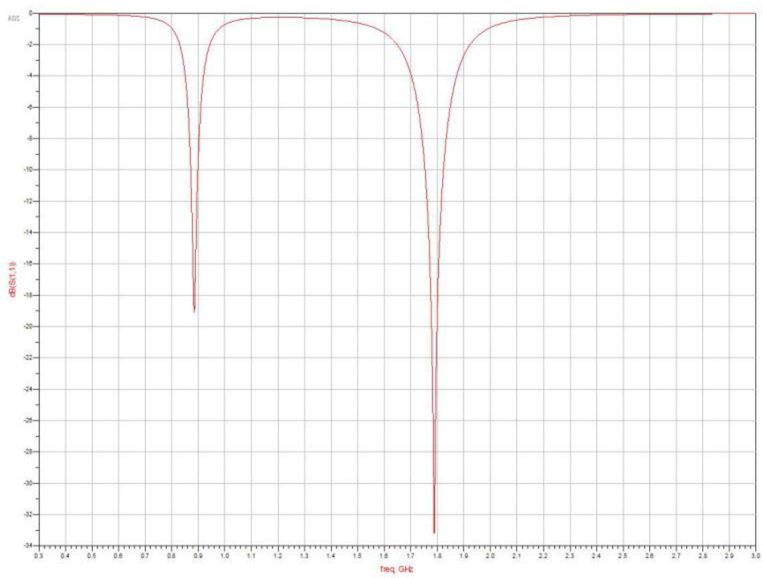
- So due to above reasons we will check for the T-stub matching impedance network.

- After the implementation of T-stub matching network with voltage Doubler circuit we can clearly see that circuit is been resonating at 900 MHz which is the ideal case.

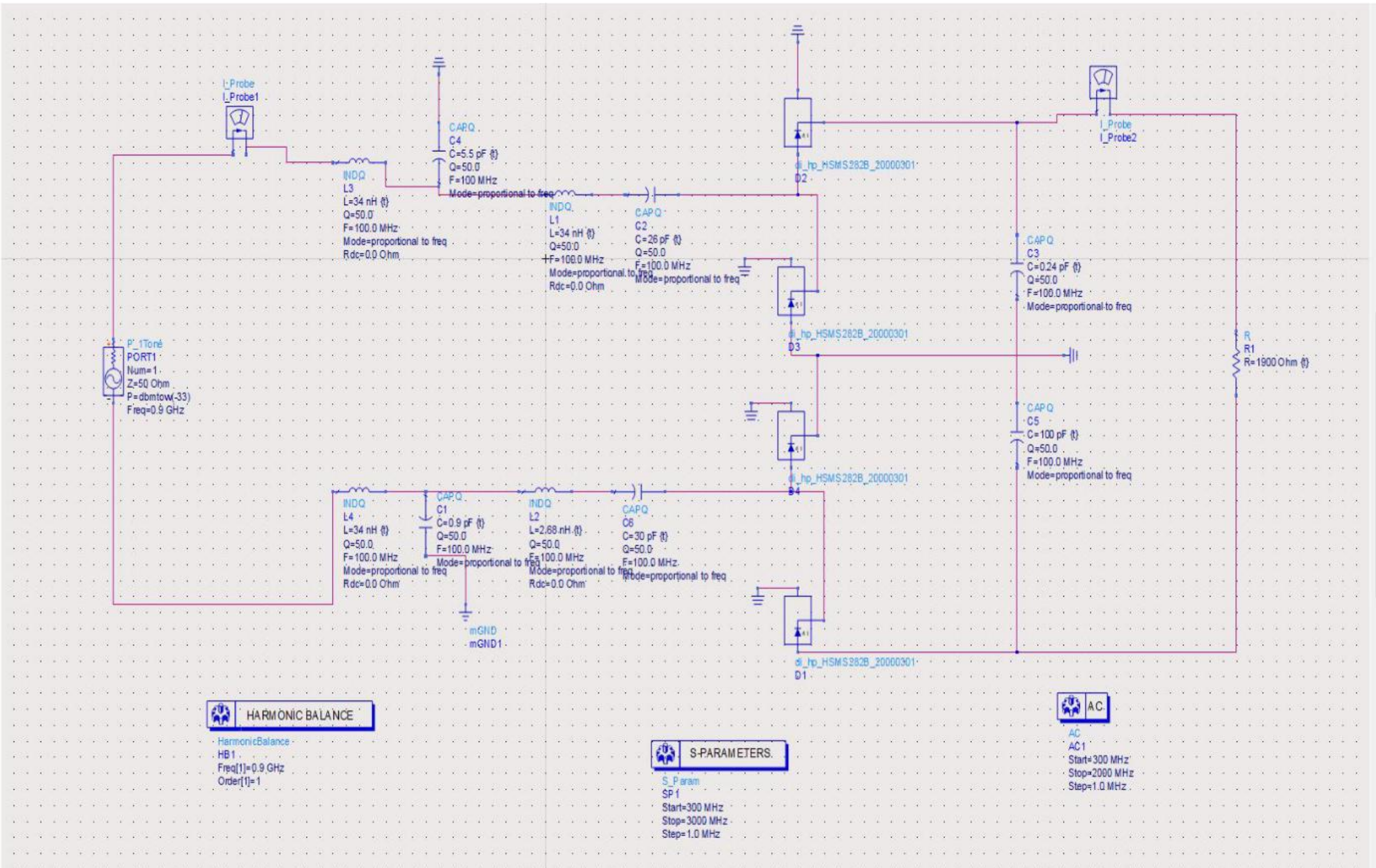
- So for this circuit T-impedance matching technique is good rather than pi-matching

Dual Band Retifier Circuit using Schottky diode with L-matching network

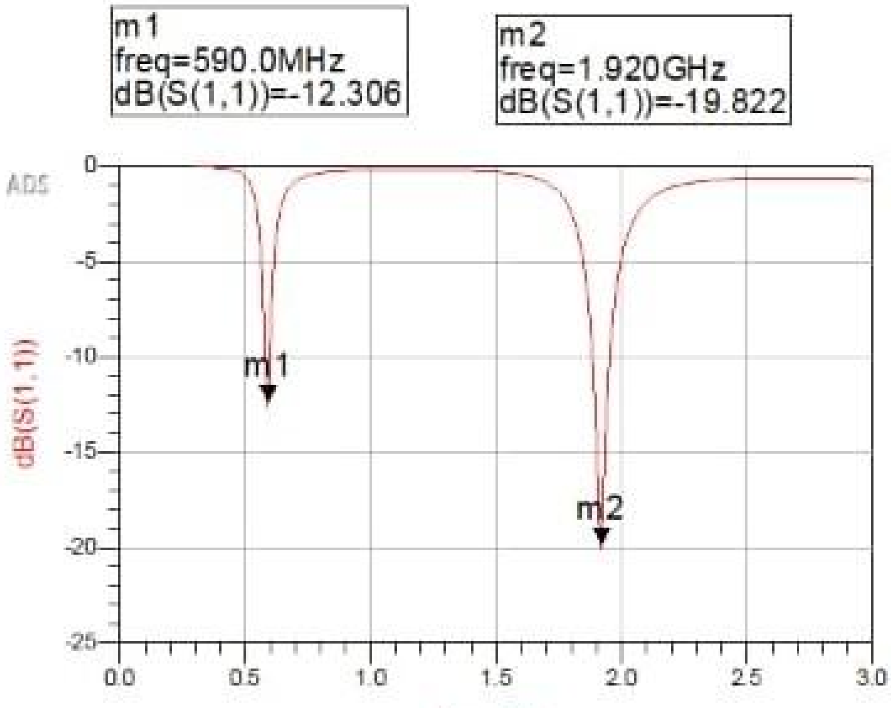




Dual Band Rectifer Circuit using Schottky Diode with T- matching network



Output Graph



Discussion:-

The above graph is the output for the T-matched dual band rectifier circuit which is not giving desired output as it is resonating at 590 MHz and 1.9 GHz which is not the desired frequencies neither the S-parameters are good . So we tried for the L-matched dual band rectifier circuit.

Results and Discussions

- The above circuit that is made using L - matched network along with Schottky diodes acts as a Dual Band rectifier circuit and hence we get the desired output as it is been resonating at two desired frequencies which are 900 MHz and 1800 MHz.

- The L-matching circuits are simpler than T-matching. It requires less components as compared to T-matching networks.

- The L-matching network shows more flexibiltiy in choosing the values of the reactive components.

- The L-matching network generally have higher efficiency compared to T-matching circuits. Moreover T-matching network is used for wide band of frequencies while L-matching is used for narrower band of frequencies as compared to the T-network.

- Also T-matched network that used earlier was resonating at 12 dB and -19 dB but the L-network that we used after T-matching is resonating at -19 dB and -34 dB which is much better results.

CONCLUSION

In this system dual band rectifier was developed and implemented for RF energy harvesting applications in implantable medical devices. The system consisted of a matching circuit, a voltage doubler rectifier circuit and a load resistor. The impedance matching was optimized.

We got the resonating graph at frequencies of 900MHz and 1800MHz which acted as a dual band rectifier. Schottky diode was used for a better working of a circuit and faster switching speed which lead to better efficiency.

FUTURE WORK

The future work of the project will include the integration of a antenna to the dual band rectifier circuit which will be simulated using HFSS tool. The antenna will play a crucial role in capturing and collecting the radio frequency (RF) energy from the surrounding environment.

The antenna will be designed to match the impedance of the rectifying circuit, so that the maximum power can be transferred from the antenna to the rectifier. The dual band antenna is more efficient as it will enable the device for harvesting more energy efficiently at two distinct frequency bands which expands the operating range and improves the reliabiltiy of the energy harvesting system.

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