National Institute of Technology Karnataka, Surathkal

Department of Electronics and Communication Engineering

EC732

RF CIRCUIT DESIGN TERM PROJECT REPORT

WIRELESS POWER TRANSFER SIMULATION

Submitted in partial fulfilment of the requirements for the Degree of Master of technology

by

GORLLA ABHIRAM CHOWDARY

Reg no: 222CN011

ROHIT KUMAR

Reg no: 222CN027

Under the Guidance of

Mr B.NAGAVEL(Assistant Professor)

Abstract

A rectenna is a type of antenna that is designed to convert radio frequency waves into direct current (DC) power. This process is known as rectification. Rectennas are commonly used in microwave wireless power transmission systems. In this project, the design of a novel 2.45 GHz patch antenna and a rectifier with an impedance matching circuit was undertaken using MATLAB and Advanced Design System software. The results indicate that the antenna has a gain of 8.01 dB, while the rectenna produces a power output of 0.075 watts with a current of 27 mA for a load resistance of 100 ohms.

Contents

Chapter 1

Introduction

Microwave wireless power transmission has a long history, dating back to the development of high-power microwave emitters known as cavity magnetrons during World War II. Since then, there have been many advances in the field of microwave power transmission. In 1964, William C. Brown built a miniature helicopter equipped with a rectenna, which is a combination of an antenna and a rectifier device. A rectenna typically consists of an antenna, a diode, an impedance matching circuit, a bypass capacitor, and a load. There are many types of antennas that can be used in wireless applications, but patch antennas are a popular choice due to their simplicity and effectiveness.

In this project report, the design of a patch antenna and a rectification unit with an impedance matching circuit and an RF bypass capacitor is presented. The complete design was carried out using Advanced Design System software.

Chapter 2

RECTENNA AND RECTIFER DESIGN

PATCH ANTENNA

A patch antenna consists of a radiating patch on a substrate, with a ground plane on one side of the substrate. Substrates with low dielectric constants are generally preferred for maximum radiation. The patch can be in a rectangular or circular shape, as these configurations are easy to analyze. Other shapes are more complex and require extensive numerical calculations. A microstrip antenna is characterized by its length, width, input impedance, gain, and radiation patterns. The length of the antenna is usually around half a wavelength in the dielectric, which determines the resonant frequency of the antenna. Patch antennas are commonly used in spacecraft, aircraft, missiles, satellites, and other applications because they are lightweight, small, easy to install, and easy to fabricate, and they produce less aerodynamic drag.

FEED TECHNIQUE

There are several different techniques that can be used to connect a coaxial cable to a microstrip patch antenna. These techniques can be divided into two categories: contacting and non-contacting. Coaxial feed and microstrip feed are examples of contacting techniques, while aperture coupling and proximity coupling are examples of non-contacting techniques. In a contacting technique, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In a non-contacting technique, electromagnetic field coupling is used to transfer power between the microstrip line and the radiating patch. In this design, the microstrip feed technique is used, which involves directly connecting a microstrip line to the radiating patch

MICRO STRIP FEED

The microstrip feed line consists of a conducting strip that is narrower than the radiating patch. It is easy to fabricate and can be easily matched by adjusting the inset position. The microstrip feed line can be etched onto the same substrate as the patch antenna, resulting in a planar structure. The inset cut in the patch is used to match the impedance of the feed line to the patch without the need for additional matching elements. This is achieved by carefully controlling the position of the insert.

DESIGN OF PATCH ANTENNA

The micro strip patch antenna is operating at 2.45GHz using the substrate material RT5880. The dielectric constant of the substrate is 2.2 and the thickness of the material is 1.6mm.

Width of the patch antenna is

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon_{r+1}}{2}}} \tag{2.1}$$

where

$$\begin{aligned} \mathrm{c} &= \text{ speed of light} \\ \mathrm{f} &= \text{ operating frequency} \\ \varepsilon_{\mathrm{r}} &= \text{ dielectric constant} \end{aligned}$$

Effective Length of the patch antenna is

$$\text{Leff } = \frac{c}{2f\sqrt{\varepsilon_{\text{eref}}}} \tag{2.2}$$

where

$$\begin{aligned} \varepsilon_{\text{eref}} &= \text{ effective dielectric constant} \\ \varepsilon_{\text{reff}} &= \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left(1 + \frac{10H}{W}\right)^{-1/2} \end{aligned}$$

Open circuit end correction length of patch antenna is

$$\Delta L = 0.412H \frac{\varepsilon_{\text{reff}} + 0.3\left(\frac{W}{H} + 0.264\right)}{\varepsilon_{\text{reff}} - 0.258\left(\frac{W}{H} + 0.8\right)}$$

The resonant length is

$$L = \text{ Leff } - 2\Delta L$$

Resonant input impedance is

$$\text{Zin} = 90 \frac{\varepsilon_r^2}{(\varepsilon_r - 1)} \left(\frac{L}{W}\right)^2$$

The input conductance of the patch fed on the edge will be twice the conductance of one of the edge slots

$$G = \frac{\pi W}{n\lambda} \left(1 - \frac{(kH)^2}{24}\right)$$

where

$$k = \frac{2\pi}{\lambda}$$
$$\text{Rin} = \frac{1}{2G}$$

The inset feed point distance Yo is obtained using

$$Rp = Re * \cos^2\left(\frac{\pi}{L} Y_o\right)$$

where Re = the input resistance of the patch fed on the edge, Rp = Probe impedance.

Design of patch antenna is implemented in MATLAB, It shows the following parameters

The wavelength (λ) = 122.4490 mm

The width of the patch (W) = 48.4022 mm

The value of Effective dielectric constant (Eeff) = 2.1077

The Effective length of the Patch (Leff) = 42.1717 mm

The extension length (ΔL) = 0.8433 mm

The actual length of patch (L) = 40.4852 mm The value of the ground plane dimensions length and width = 50.0852 mm, 58.0022 mm

The Input Impedance of the patch is (Zin) = 253.9622 mm

The value of Patch edge impedance (Rin) = 151.8320 mm

The inset feed point distance is (Yo) = 12.3661 mm

DESIGN ,SIMULATION AND RESULTS

Figure 1 shows the design of a 2.45 GHz patch antenna in MATLAB. The antenna consists of a radiating patch and a quarter-wave transformer feed line with a 50 ohm impedance. The patch antenna was designed using the specified dimensions, and the return losses were improved through trial and error. The edge of the patch antenna is matched to the 50 ohm feed line, as all cables have a 50 ohm impedance. The quarter-wave transformer line is used to connect the radiating patch to the microstrip line.

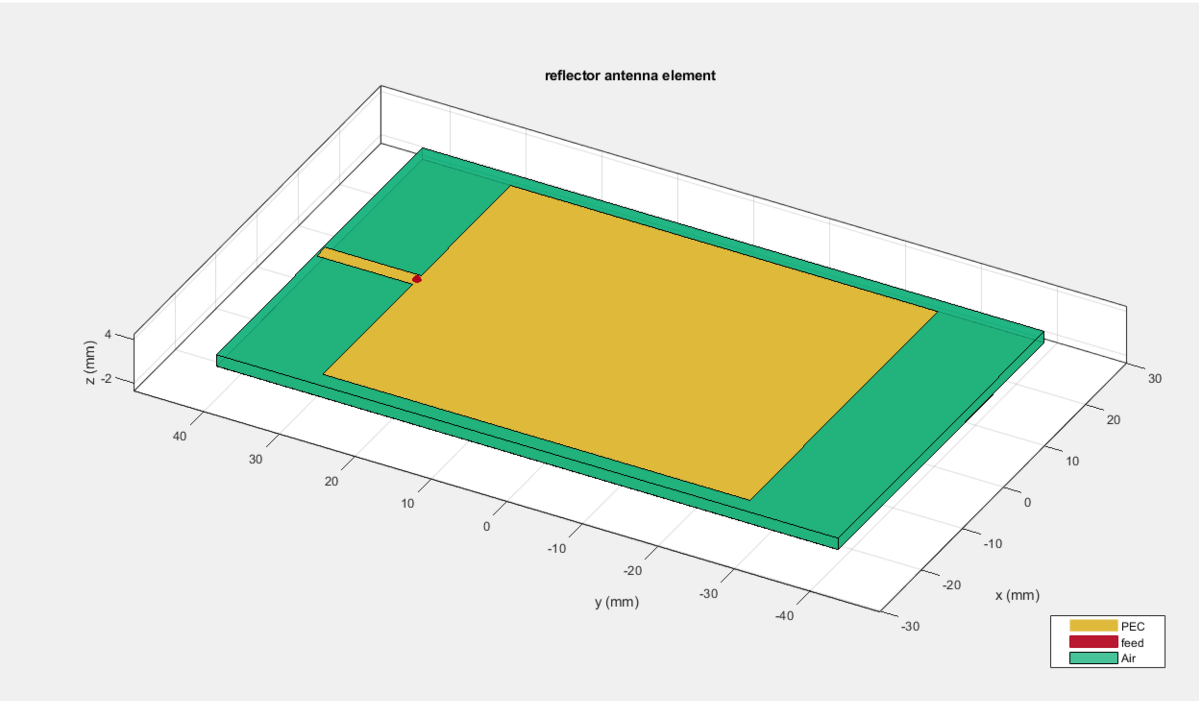

Figure 2.1: Matlab antenna designl

The results of the 2.45GHz edge feed patch antenna graph is shown in Figure below, represent s11 of antenna

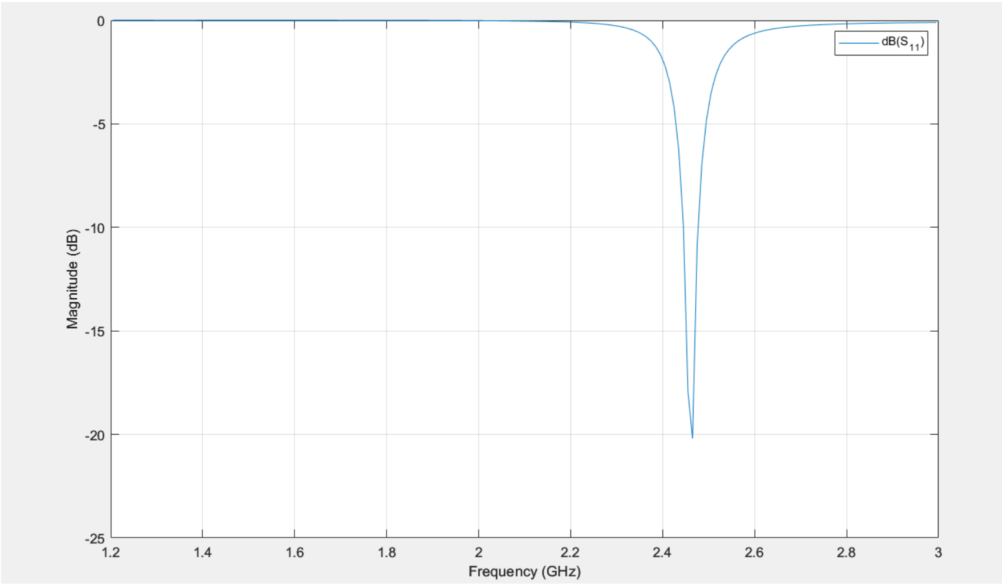

Figure 2.2: s11

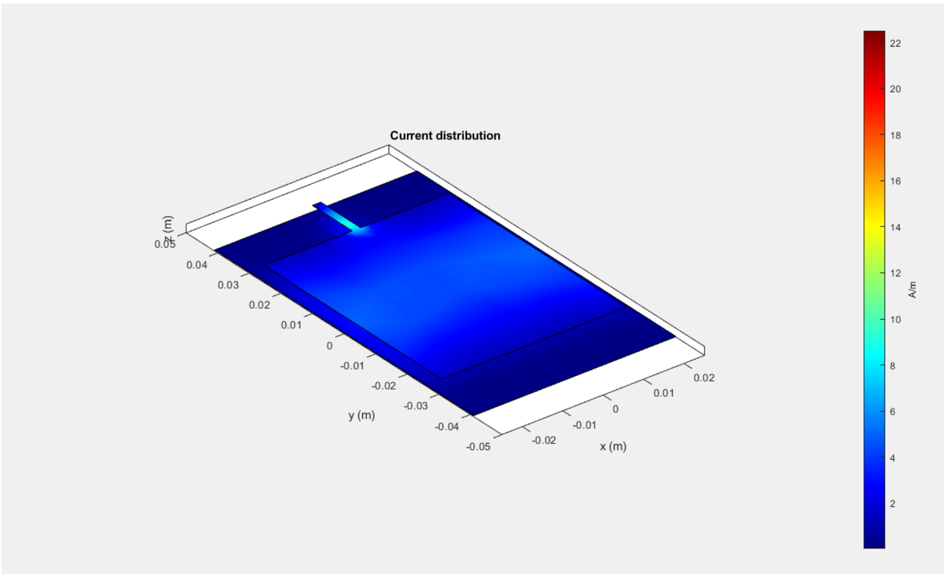

Figure 2.3: current flow

here is the radiation pattern for the antenna from Matlab.

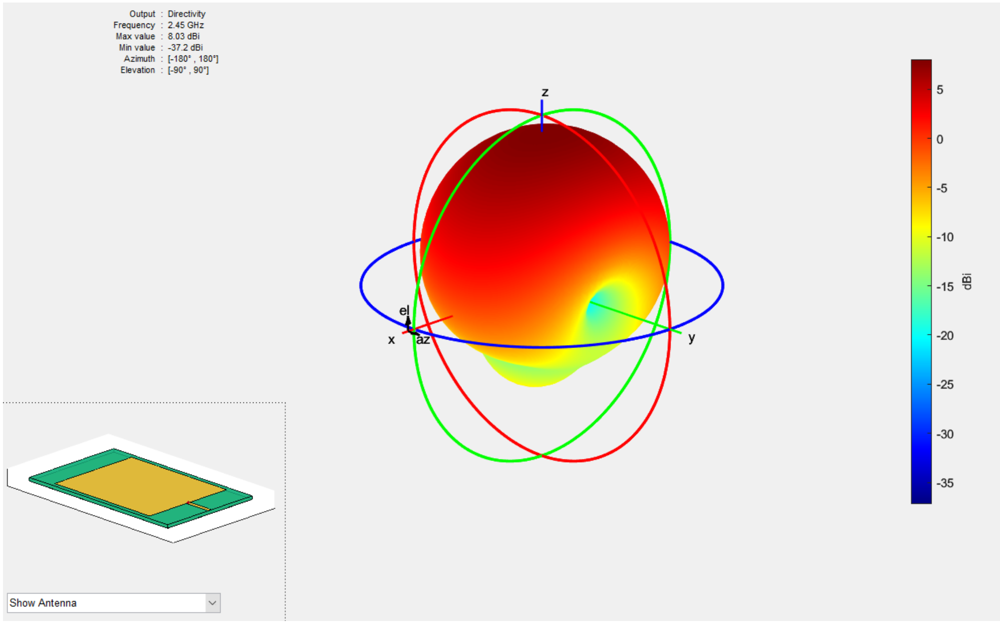

Figure 2.4: radiation pattern

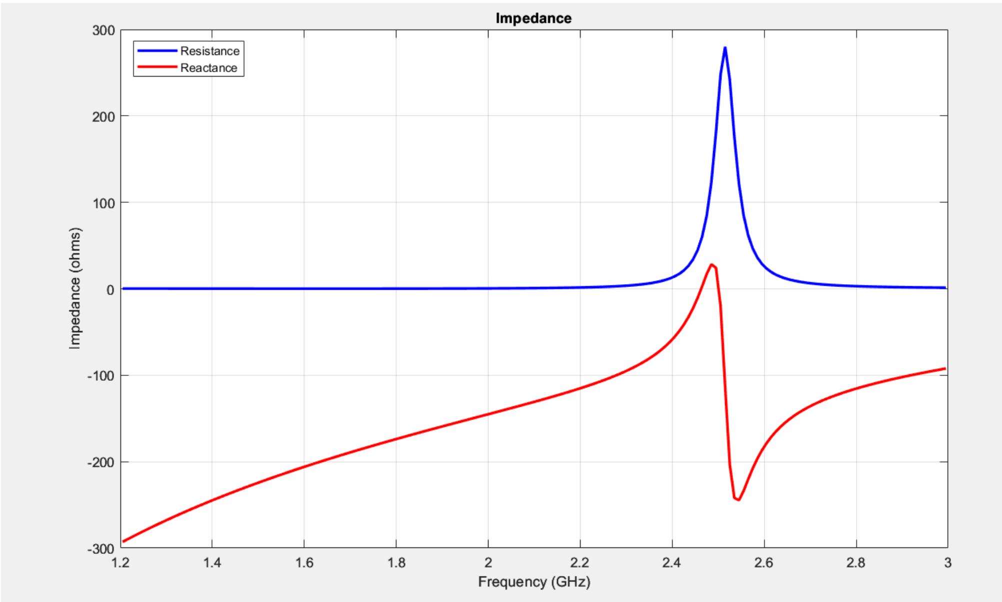

Figure 2.5: impedance

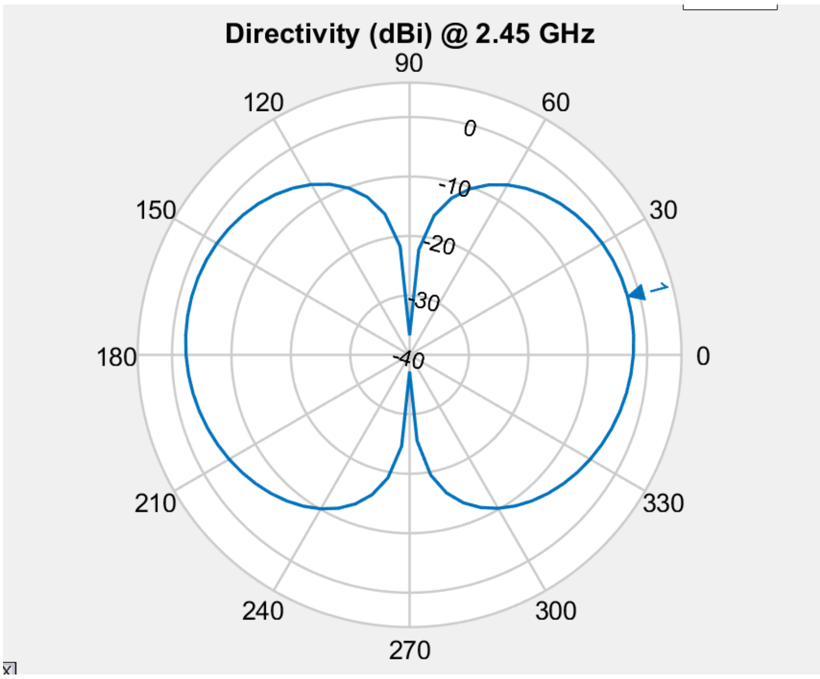

Figure 2.6: AZ plot

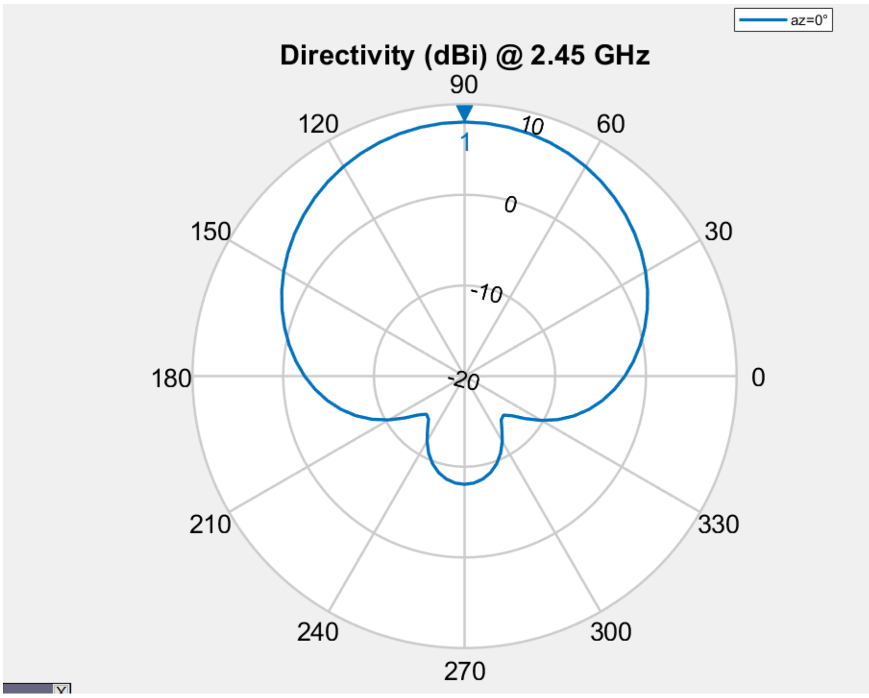

Figure 2.7: elevation plot

The Antenna parameter for Edge feed patch antenna, Peak frequency: 2.449GHz

Gain: 8.01 dB

Return loss: −20.31 dB

Bandwidth: 120MHz

RECTIFIER

The RF to DC conversion circuit consists of HSMS 2860 Schottky diode, Capacitor and impedance matching element. Schottky diode converts the RF into DC, Capacitor act as DC power storage and RF by-pass capacitor and impedance match will improve the efficiency of the Rectenna. It is developed in ADS software with the reference of HSMS 2860 Schottky diode datasheet, which is shown below figure.

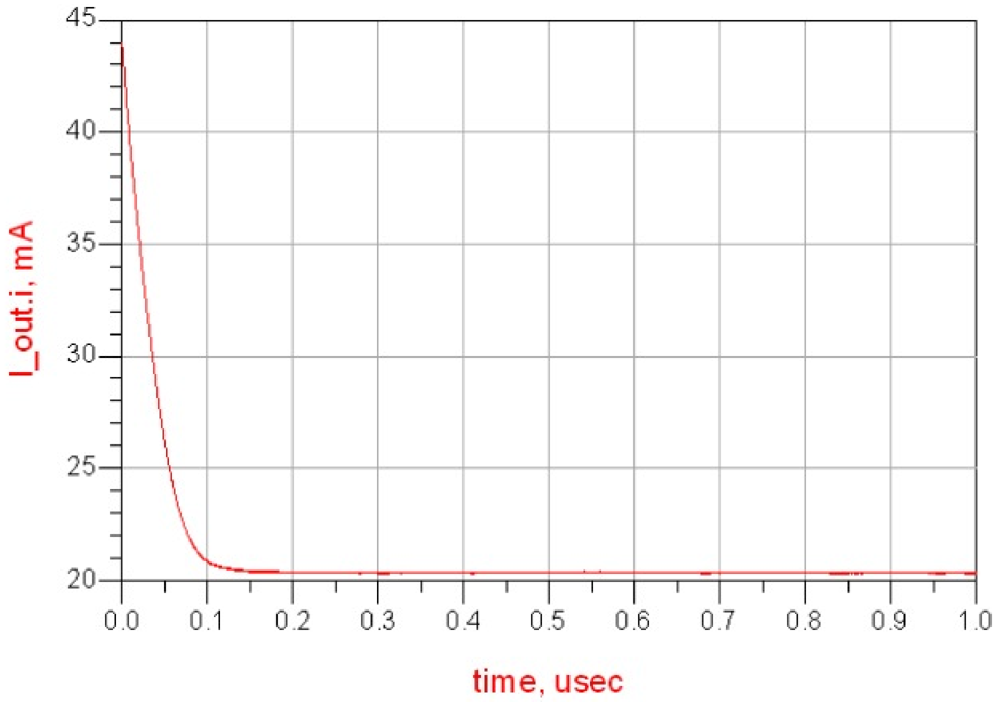

Figure 2.8: current out vs time

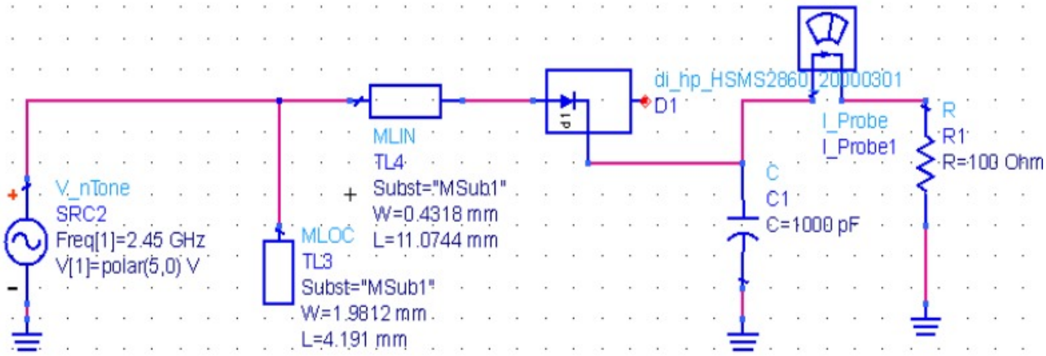

Figure 2.9: rectifier circuit

The Final ADS simulation circuit of the half-wave Rectenna design is shown in Figure below, in this, simulation produces approximately 27mA at 100Ω load and this is shown in Figure below.

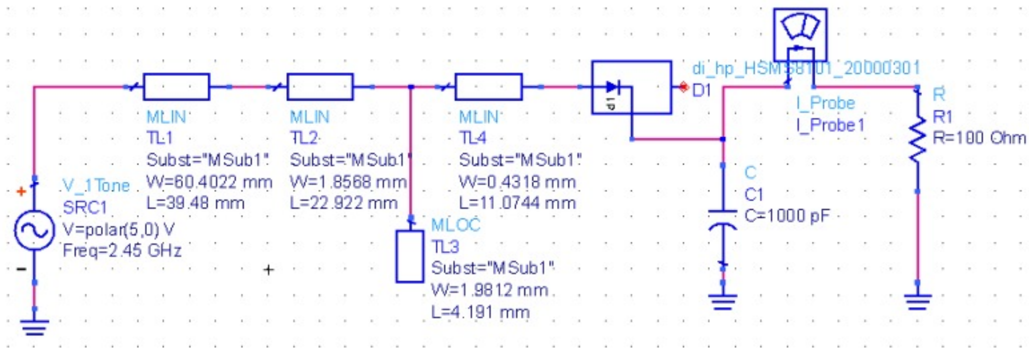

Figure 2.10: rectenna circuit

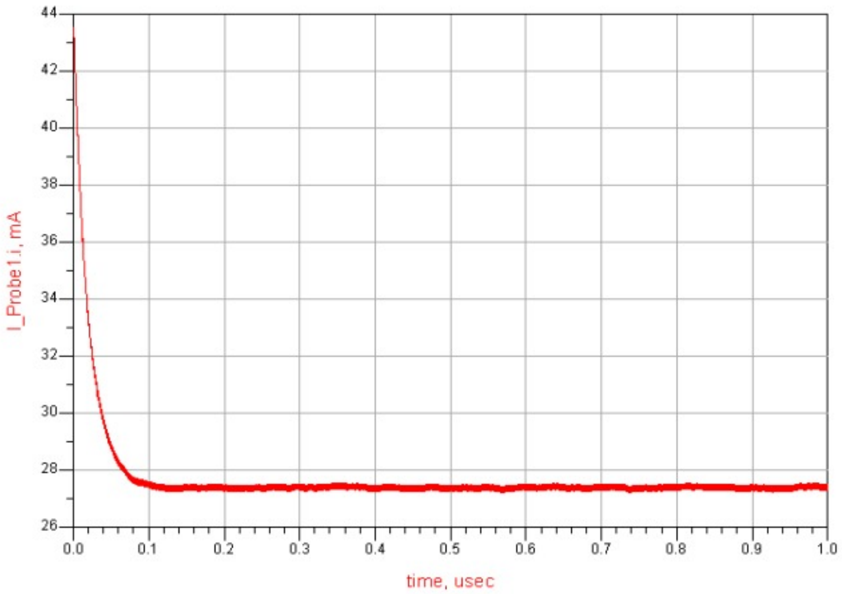

Figure 2.11: current vs time

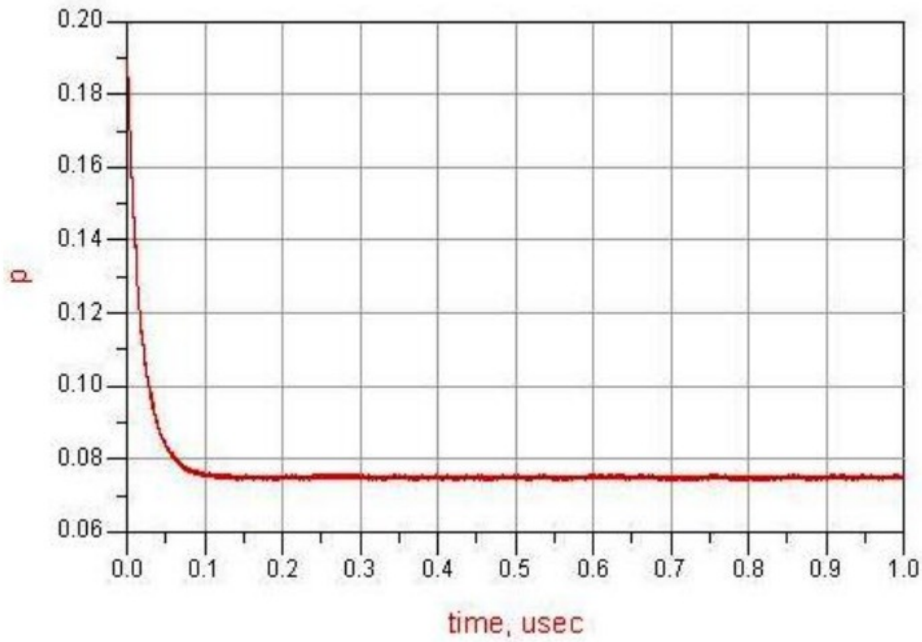

Figure 2.12: power vs time

Chapter 3

Conclusions

A complete analysis of Rectenna model for Microwave Wireless Power Transmission was made in ADS Software and matlab. It provides efficient Rectenna for Microwave Wireless Power.Transmission. Novel micro strip patch antenna operating at 2.45GHz range has been designed which provide a return loss of -20.3dB.The over all Rectenna circuit current shows approximately 27mA and output power is 0.075Watts. With such kind of high performance Rectenna, the range of received power can be improved.

References

[1] W. C. Brown, "The history of power transmission by radio waves," *IEEE Transactions on Microwave Theory and Techniques*, vol. 32, no. 9, pp. 1302–1310, 1984.

[2] M. R. Moorthi and A. Saravanakumar, "Rectenna model for 2.45ghz microwave wireless power transmission," in *2013 International Conference on Energy Efficient Technologies for Sustainability*, pp. 1360–1364, 2013.

[3] T. A. Milligan, *Modern Antenna Design.* John Wiley Sons Inc., 2 ed., 2005.

[4] A. Technologies, "Hsms 286x series, surface mount microwave schottky detector diode," May 2009.

[5] J. Zbitou and M. Latrach, "Hybrid rectenna and monolithic integrated zero-bias microwave rectifier," *IEEE Transactions on Microwave Theory and Techniques*, vol. 54, no. 1, pp. 246–252, 2006.