# DESIGN OF RECTIFING ANTENNA FOR ENERGY HARVESTING

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## I. ABSTRACT

This design project focuses on developing a rectifying antenna for energy harvesting at a frequency of 3.5 GHz. The project aims to efficiently convert electromagnetic waves in this frequency range into usable DC power. The design involves optimizing the antenna geometry, size, and matching network for reception at 3.5 GHz. Diodes, filters, and impedance matching circuits are incorporated for efficient rectification and improved performance. Simulation tools are used to analyze and optimize design parameters. The outcome will be a rectifying antenna capable of powering low-power devices using harvested energy [1]. The research contributes to energy harvesting advancements and potential applications in wireless communication, IoT, and remote sensing systems. For planning and recreation of proposed antenna we have utilized HFSS Software tool.

*Keywords*: Rectifying antenna, harvested energy, rectification, simulation tools, HFSS

## II. INTRODUCTION

Rectifying antennas are of paramount importance in energy harvesting applications due to their ability to convert electromagnetic radiation into usable electrical energy. These antennas play a crucial role in enhancing the efficiency of energy conversion processes. By making the antenna and the rectifier's impedances better matched, rectifying antennas ensure that a significant portion of the captured energy is effectively converted into usable electrical power [2]. This increased energy conversion efficiency is vital in maximizing the overall energy harvesting performance.

One significant advantage of rectifying antennas is their ability to enable wireless power transfer. By harnessing electromagnetic radiation, such as radio waves or microwaves, these antennas allow for the remote powering of devices without the need for physical connections or reliance on batteries [3]. This capability is especially valuable in applications where battery replacement or maintenance is challenging or impractical, such as in remote sensors, wearable devices, or Internet of Things (IoT) devices. Rectifying antennas permit the wireless transmission of power, providing a convenient and efficient means of energizing electronic devices.

Another key aspect of rectifying antennas is their ability to harvest ambient energy from various sources. These antennas can capture and convert wasted energy from radio frequency (RF) signals, Wi-Fi networks, cellular networks, and other ambient electromagnetic radiation. By tapping into these readily available energy sources, rectifying antennas allow for the powering of low-power electronics and contribute to energy efficiency and sustainability efforts[4]. The ability to harvest energy from the surrounding environment presents significant opportunities for reducing dependence on conventional power sources and promoting the utilization of clean, renewable energy.

The utilization of rectifying antennas not only benefits specific industries but also contributes to overall green energy solutions. By efficiently harvesting energy from ambient sources, these antennas offer an alternative to conventional power sources, reducing the environmental impact associated with battery disposal and replacement. They enable the implementation of sustainable energy solutions, aligning with the goals of energy efficiency and environmental preservation[5].

In summary, rectifying antennas are instrumental in energy harvesting due to their enhanced energy conversion efficiency, ability to facilitate wireless power transfer, capacity to harvest ambient energy, versatility in applications and scalability, as well as their contribution to green energy solutions [6]. These antennas enable the efficient conversion of electromagnetic radiation into usable electrical power, unlocking numerous possibilities for self-powered devices and promoting sustainable energy practices.

### III. RECTIFYING ANTENNA IN ENERGY HARVESTING

In order to transform electromagnetic waves into usable direct current (DC) power, a rectifying antenna, sometimes called a rectenna, combines an antenna and a rectifier. It is frequently employed in energy harvesting applications where RF waves, a kind of ambient electromagnetic radiation, are transformed into electrical energy [8].

Here's how a rectifying antenna works:

1. Antenna: The antenna component of the rectifying antenna is designed to efficiently capture the incoming electromagnetic waves. It can be designed for a specific frequency range or be broadband to capture a wide range of frequencies.

2. Rectifier: The rectifier is in charge of transforming the induced alternating current (AC) signal into DC power. Usually, it is made out of diodes arranged in a certain pattern, such a voltage doubler or a full-wave rectifier. The diodes restrict the direction of current flow, rectifying the AC signal.

3. Filtering and Matching: To enhance the functionality of the rectifying antenna, extra parts like filters and impedance matching circuits may occasionally be used. While impedance matching circuits optimize power transfer between the antenna and the rectifier, filters assist in eliminating undesirable frequencies.

4. Power Harvesting: As the rectifying antenna captures electromagnetic waves, the AC signal generated in the antenna is rectified by the diodes, resulting in a pulsating DC voltage. This pulsating DC voltage is then filtered to smooth out the waveform and produce a usable DC power output.

Rectifying antennas are often used in wireless power transfer applications, where they can harvest energy from ambient RF waves present in the environment. This technology has the potential to power small electronic devices, sensors, and low-power wireless communication systems without the need for batteries or wired connections. However, the efficiency of rectifying antennas can vary depending on factors such as the frequency range, antenna design, and surrounding environmental conditions [10].

It's worth noting that while rectifying antennas can provide a convenient means of energy harvesting, the amount of power generated is typically limited. They are most effective in scenarios where the ambient RF energy is relatively strong and can be efficiently converted into usable power.
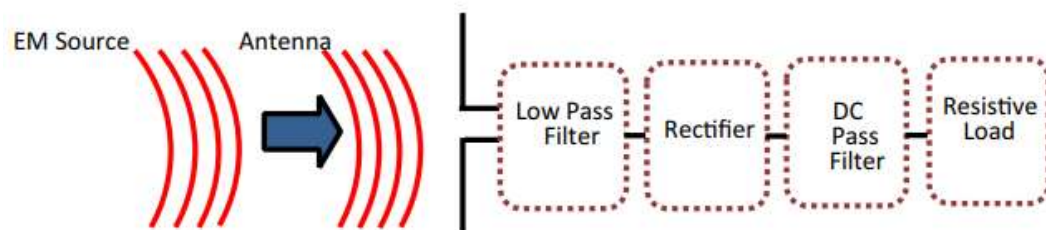


**Figure1:** Block diagram of a simple rectenna system

As seen in Fig. 1, the main components of a rectenna system are the receiving antenna, low pass filter (LPF), matching circuitry, rectifier, and a DC pass filter.

### IV. ANTENNA DESIGN

Here is an illustration of the designed antenna with structural specifications. The FR4 substrate with a 4.4 dielectric constant is used to assemble this antenna. 1.6 mm of substrate height.

The suggested aerial design is depicted in Figure 2. A, B, C, and D, respectively, display its top, back, front, and dimetric views. The aerial is made up of the ground plane, substrate, and patch, or radiating element. While the patch has rectangular cuttings, the ground plane features triangular and rectangular slots..

A ground plane with triangular slots is positioned behind the substrate, and the performance of the antenna is greatly influenced by the current distribution on its ground element.
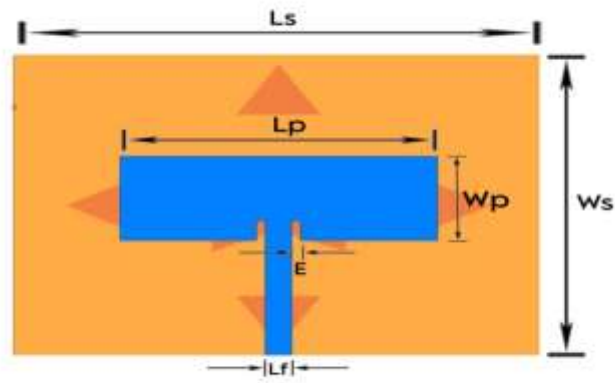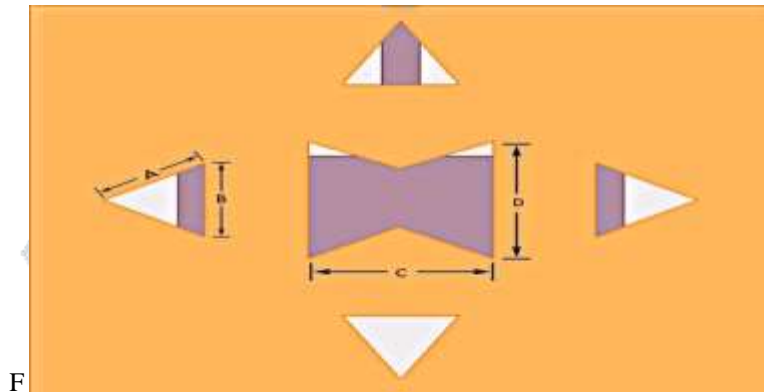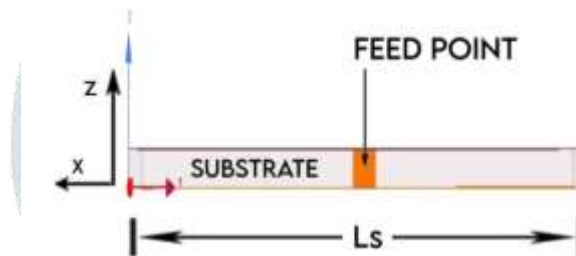
**Fig 2A:** Top View



**Fig 2B:** Bottom View



**Fig 2C:** Front View
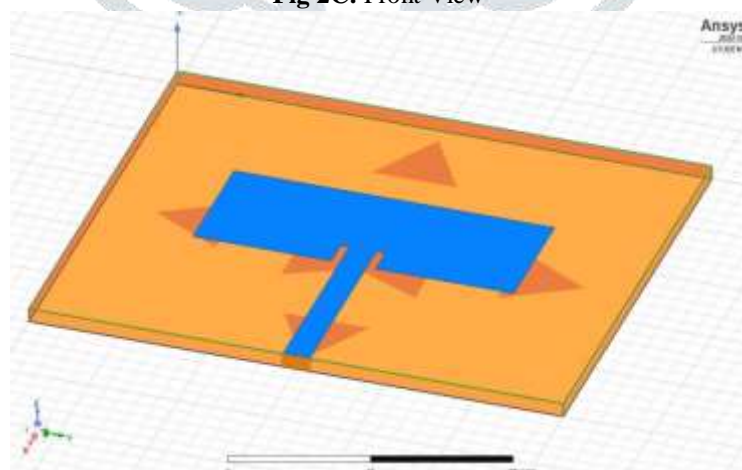


**Fig 2D:** Dimetric View

## V. ANTENNA DIMENSIONS

| S.No. | Parameter | Measurement |
|-------|-----------|-------------|
| 1. | $L_S$ | 60mm |
| 2. | $W_S$ | 50mm |
| 3. | $H_S$ | 1.6mm |
| 4. | $L_P$ | 36mm |
| 5. | $W_P$ | 13.8mm |
| 6. | Lf | 3mm |
| 7. | A | 6mm |
| 8. | B | 12mm |
| 9. | C | 30mm |
| 10. | D | 20mm |
| 11. | E | 1mm |

**Table1:** Design Antenna Parameters

## VI. DESIGN SPECIFICATIONS

- $f_0$ = frequency = 3.5GHz.
- Dielectric constant of substrate $(\epsilon_r)$ = 4.4mm
- Thickness of substrate = 1.6mm.

## VII. ANTENNA DESIGN FORMULAE

   i. The patch length and width of MSA can be found by using the following formulae:

   ii. Width of patch = W = $\frac{c}{2f_0}\sqrt{\frac{\epsilon_r+1}{2}}$

   iii. Effective dielectric constant, $\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r+1}{2}\left[1 + \frac{10h}{w}\right]^{-1/2}$

   iv. Length added due to fringing field, $\Delta L = \frac{h}{\sqrt{\epsilon e}}$

   v. Effective length, $L_e = \frac{C}{2f_0\sqrt{\epsilon e}} = L + 2\Delta L$

   vi. Length of patch, $L = L_e - 2\Delta L$

## VIII. SIMULATION RESULTS

### A. Scattering pattern (S11):

S-parameters, or scattering parameters, are used to determine an antenna's return loss. The term "return loss" refers to the quantity of incident energy that is lost and sent back to the source. Decibels (dB) are used to quantify it and it is calculated as the reciprocal of the power of the incident wave to the power of the reflected wave.

The reflection coefficient, also referred to as the magnitude of S11, can be expressed as a percentage or in decibels (dB). A higher return loss indicates improved antenna performance since more energy is being sent into the antenna and less is being reflected back.
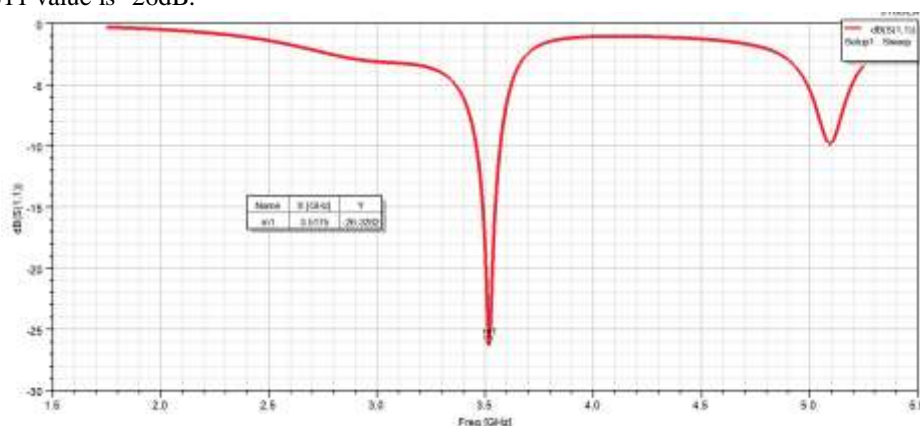
Here, the obtained S11 value is -26dB.



**Fig 3**: S Parameters diagram used to find return loss

**B. Gain:**

When comparing a signal's strength in one direction to the signal strength that would be received from an isotropic radiator transmitting the same power, one may calculate the gain of an antenna, which is expressed in decibels (dB).

The antenna is more directional the higher the gain, which results in more efficient energy radiation in a particular direction and stronger signal strength in that direction.

Here, the obtained Gain value is 4.23 dB
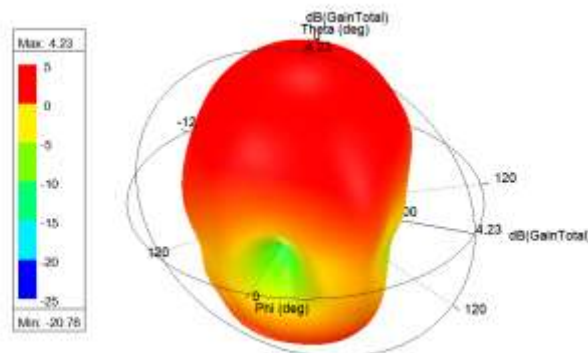


**Fig 4:** Gain of Rectifying Antenna

**C.VSWR:**

The voltage standing wave ratio (VSWR), which stands for "Voltage Standing Wave Ratio," measures how well an antenna matches the transmission line or feedline that joins the antenna to the transmitter or receiver.

The maximum voltage to the minimum voltage along the transmission line is measured by VSWR, which is typically stated as a ratio or in decibels.
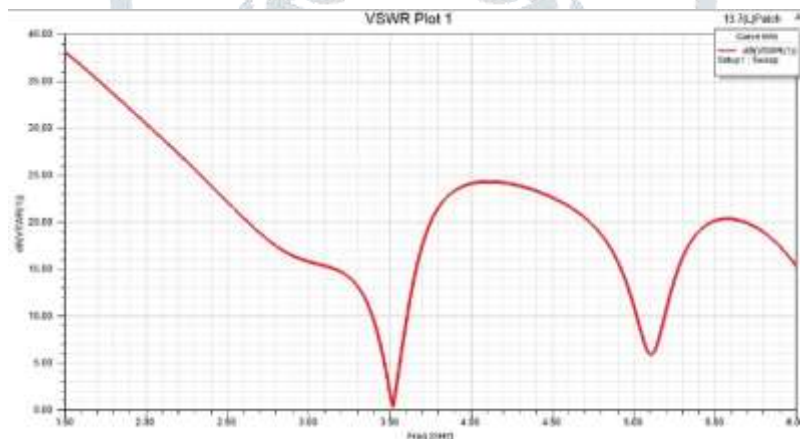


**Fig 5:** VSWR of Rectifying Antenna
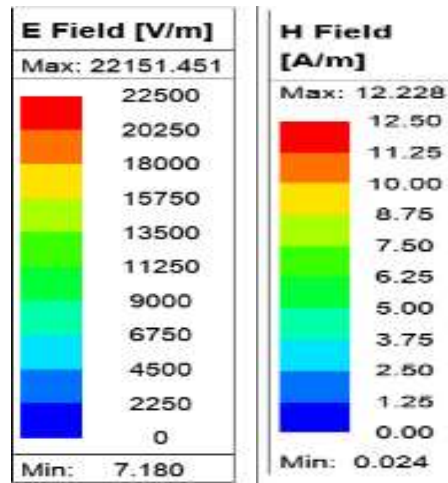
**D. Radiation Pattern**

The term "radiation pattern" refers to a mathematical function or graphical representation of the characteristics of the antenna's far field radiation (i.e., for $r \gg 2D^2/\lambda$ , where D is the antenna's maximum dimension) as a function of the direction from which the electromagnetic (EM) wave originates.
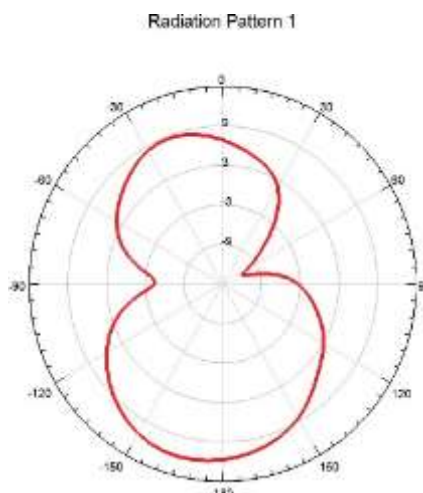


Fig 6: Radiation Pattern of Rectifying Antenna

**E. Current Distribution in E-Field & H-Field:**

The current distribution of electric field (E-field) & magnetic field (H- field) are fundamental characteristics antennas that are closely related to each other. This shows the values of E-Field and H-Field.

| E Field [V/m] | H Field [A/m] |
|---|---|
| Max: 22151.451 | Max: 12.228 |
| 22500 | 12.50 |
| 20250 | 11.25 |
| 18000 | 10.00 |
| 15750 | 8.75 |
| 13500 | 7.50 |
| 11250 | 6.25 |
| 9000 | 5.00 |
| 6750 | 3.75 |
| 4500 | 2.50 |
| 2250 | 1.25 |
| 0 | 0.00 |
| Min: 7.180 | Min: 0.024 |

We obtained the Value of the E-Field is 22151V/m
And the value of H-Field is 12A/m.

## IX. CONCLUSION

This work presents a viable configuration for a single band high gain, high dispersion antenna that operates at 3.5GHz. The substrate's bottom is etched with optimized triangular-shaped grooves that aid in creating effective antenna settings. The size of the planet has dramatically shrunk since the advent of the internet. These factors make RF sources the most commonly used primary sources to guarantee the energy independence of wireless sensors under difficult circumstances. Thus, energy harvesting wireless sensors will help to realize the goals of the IOTs, for which everywhere real-time connectivity is required. However, work in numerous research areas contributes to the operational viability of RF energy harvesting. Thus, the ambient energy harvesting uses our constructed antenna.

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