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# Design of Elliptical Shaped Patch Antenna for RF Energy Harvesting

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***Article Info***
***Volume 83***
***Page Number: 9314 - 9320***
***Publication Issue:***
***March - April 2020***

***Article History***
***Article Received****: 24 July 2019*
***Revised****: 12 September 2019*
***Accepted****: 15 February 2020*
***Publication****: 09 April 2020*

## Abstract

In this work an elliptical shaped patch antenna for 8 GHz frequency is designed along with the RF energy harvesting circuit. The elliptical shaped patch antenna was designed and simulated using HFSS results with gain (7.5dBi), directivity (7.4dBi) and efficiency (89%). The antenna is fabricated using FR-4 material and was tested. The simulated and fabricated antenna results are then compared and then found that fabricated antenna results are much better than the simulated results. Then the matching network was designed using ADS software along with 50Ω line as it is used to exactly match the circuit with ambient resistance. The half wave rectifier circuit is also designed in ADS for converting the harvested RF energy to its equivalent DC voltage. The overall module can capture RF energy from ambient which is converted to 0.767V by the rectifier circuit which can be used to on and off any low power sensor networks. Further with the design of suitable voltage multiplier circuits the generated DC voltage can be increased.

## I. INTRODUCTION

Energy is available everywhere in the environment surrounding us and it is available in the form of thermal energy, light energy (Solar), wind energy and mechanical energy. The energy from the mentioned sources are often found in such small quantities so that it cannot supply adequate power for any low power. So far, it has not been possible to capture such energy adequately to perform any useful work and it can be changed using a method energy harvesting. Energy Harvesting is the process by which energy from the environment are captured in small quantities capturing small amount of energy from multiple naturally occurring energy sources, accumulating them and storing them for future purpose. These devices perform accurately by capturing, accumulating, storing and managing this energy which will be supplied in a form that can be used to perform a helpful task.

## II. ARCHITECTURE

Typically, a module of Energy Harvesting is an electronic device that can perform all these functions to power a variety of sensor and control circuitry for intermittent duty applications. It is also known as energy scavenging or micro energy harvesting. However the energy captured is adequate for most wireless applications, remote sensing, body implants and other applications as the lower segments of the power spectrum and even if the powering device has low harvested energy, it can still be used to extend the life of a battery. The typical block diagram of the RF energy harvesting circuit is given below

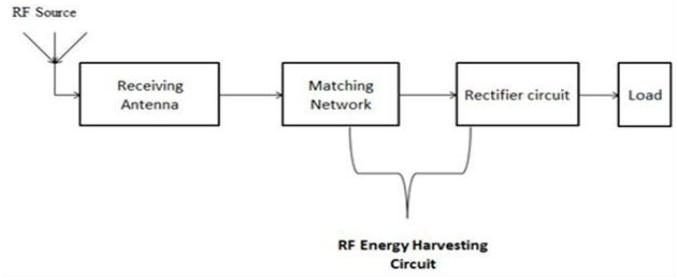


**Fig 1. RF Energy Harvesting Circuit**



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### A. Antenna Design

The antenna is segmented into three main parts; Main radiating patch, Ground patch and Feed line. The various shapes of antennas were designed using HFSS and the important parameters were tabulated.

| SHAPES | FREQUENCY | GAIN(dBi) | EFFICIENCY (%) |
|---|---|---|---|
| Rectangle | 8 GHz | 7.1 | 85 |
| Square | | 6.9 | 80 |
| Circle | | 7.12 | 84 |
| Elliptical | | 7.4 | 89 |

**Table1. Comparison of various shapes of Antenna**

The high gain and high efficiency antennas are best suited for the RF energy harvesting applications as it will generate more output DC voltage from the rectifier circuit. So the elliptical shaped patch antenna was chosen as the main radiating patch with the dielectric constant of 2.2 and loss tangent is 0.009 and the substrate material used is RT Duroid. The feed line used is inset feed since it needs only minimal matching circuit. For Fabrication purpose FR4 material is used because of low cost.

### B. Energy Harvesting Rectifier Circuit

ADS software is used to design energy harvesting circuit. The S11 parameter file S1P of the designed elliptical antenna is imported to the ADS RF simulator which is done to have a proper impedance matching between the output of the antenna and half-wave rectifier circuit. Rectifier circuit is build using diodes and in half-wave rectifier we need the positive side signals only. The monotonic frequency power source is used to excite the rectifier circuit. The S1P has two pins which are grounded and connected with the Pin 3 coupler. The rectifier device is connected with the coupler on the other side via the impedance matching network. Single tone excitation is applied as input and the matching circuit for the required device is designed similar to L-C impedance matching network, so that the rectifier is matched to the antenna at 50 ohm for the desired 8GHz frequency.

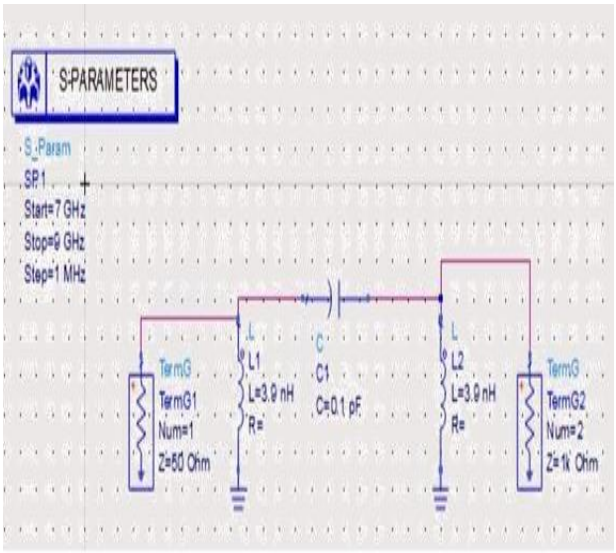


**Fig 2. Matching network circuit**

## III. METHODOLOGY

### A.Existing Method

In the existing method they designed a rectenna for the frequency 5.8GHz using ADS software as the simulation tool for the microstrip planar antenna[9]. The output of the antenna and rectifier circuit is matched to a impedance of 50Ω line over the ISM frequency band[9] using a matching network. The simulated antenna results are given below.

| PARAMETERS | VALUES |
|---|---|
| Frequency | 5.8GHz |
| Gain(dBi) | 2.89 |
| Directivity(dBi) | 3.638 |
| Efficiency(%) | 84 |

**Table 2. Antenna Parameters at 5.8GHz**

### B. Flow Chart

The overall process of the methodology is given as a flowchart



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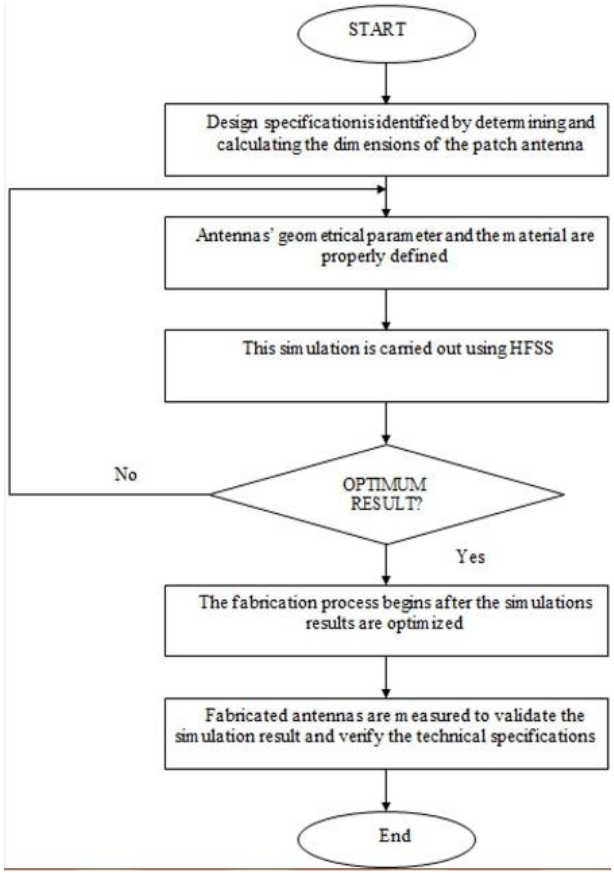


**Fig 3. Process Flow chart**

### C. Proposed Method

In this method we design an elliptical shaped microstrip patch antenna with inset feed for frequency 8GHz using HFSS software along with matching network and rectifier circuit in ADS software

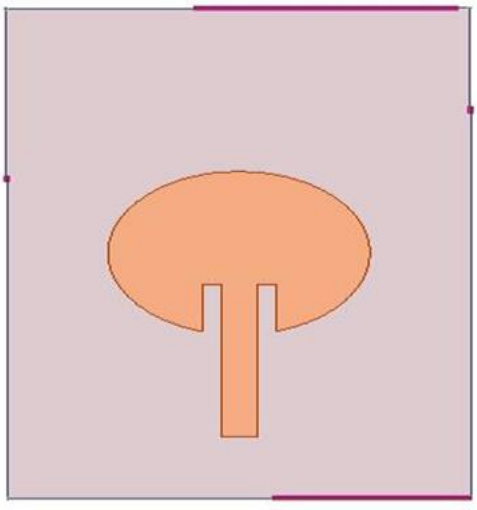

**Fig 4. Proposed Elliptical Shaped Antenna**

The various design parameters are optimized in order to achieve the high gain and efficiency and the final values of the design parameters are given below.

| Design Parameters | Values (mm) |
|---|---|
| a (minor axis) | 7.23 |
| b (major axis) | 8.63 |
| Feed line width | 2.426 |
| Inset feed gap | 1.213 |
| Inset feed length | 4.1 |
| Ground length | 43 |
| Ground Width | 30 |

**Table 2. Design parameters of the antenna at 8GHz**

The antenna is then fabricated for testing using FR4 substrate

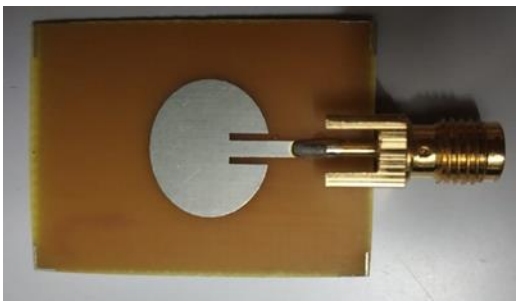

**Fig 5. Fabricated antenna at 8 GHz**

## IV. TEST AND RESULTS

In this proposed model we design a microstrip patch antenna, a matching circuit and a half-wave rectifier circuit. First the antenna is designed using HFSS software for 8 GHz frequency. An elliptical antenna is designed for the frequency 8 GHz using HFSS software and inset feed is given for this antenna. It is then simulated to calculate the Return loss, VSWR, Gain and Efficiency of the antenna for the given frequency.



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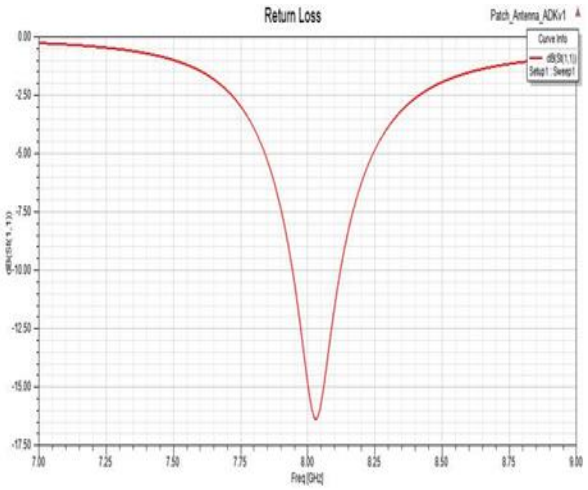


**Fig 6. Return loss of the antenna at 8GHz**

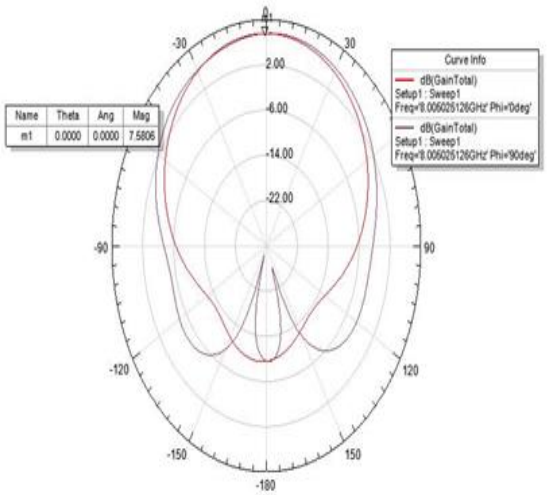


**Fig 7. Gain of the antenna at 8GHz**

From the graph, the antenna has a return loss of -16.5 dB which is very well suited to get maximum incident waves at the receiver side. The various other output parameters are given in the table below

| Output Parameters | Values |
|---|---|
| Frequency | 8 GHz |
| Radiated Power (Watts) | 0.00041 |
| Directivity (dBi) | 7.4 |
| Radiation Efficiency (%) | 89 |
| Gain (dBi) | 7.5 |

**Table 3. Output parameters of the antenna at 8GHz**

Basically we design antenna for 50 ohm and it will have to match the impedance of the load and for that we are using a matching network along with rectifier. In this, first we design circuit with general 50 ohm circuit and then we match the network to the load resistance. After matching that we import antenna S(1,1) parameter from the HFSS software to ADS software and then it is tuned for the given circuit and it is matched.

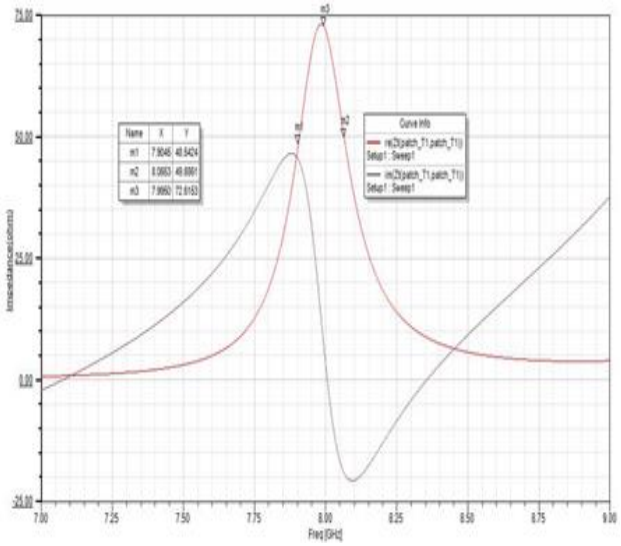


**Fig 8. Impedance of the antenna at 8GHz**

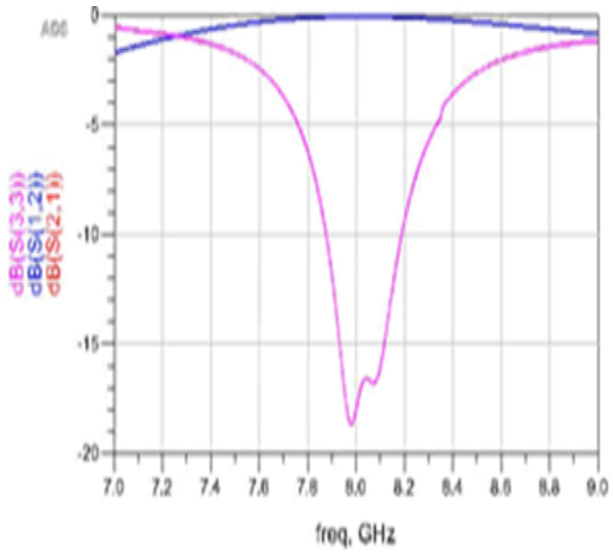


**Fig 9. Frequency Vs S33, S12, S21**

The simulated output parameters of proposed and existing antennas were compared and the proposed elliptical shaped antenna was found to be the best for RF energy harvesting



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| PARAMETERS | EXISTING ANTENNA | PROPOSED ANTENNA |
|---|---|---|
| Frequency | 5.8GHz | 8GHz |
| Gain (dBi) | 2.89 | 7.5 |
| Directivity (dBi) | 3.638 | 7.4 |
| Efficiency (%) | 84 | 89 |

**Table 4. Comparison of Existing and Proposed antenna**

The antennais fabricated for 8GHz and it is tested using network analyser. The experimental setup of network analyser and the fabricated antenna is shown in the figure.

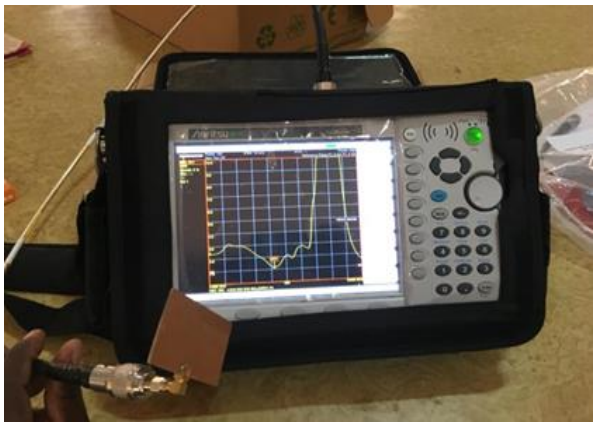

**Fig 10. Experimental setup of the antenna**

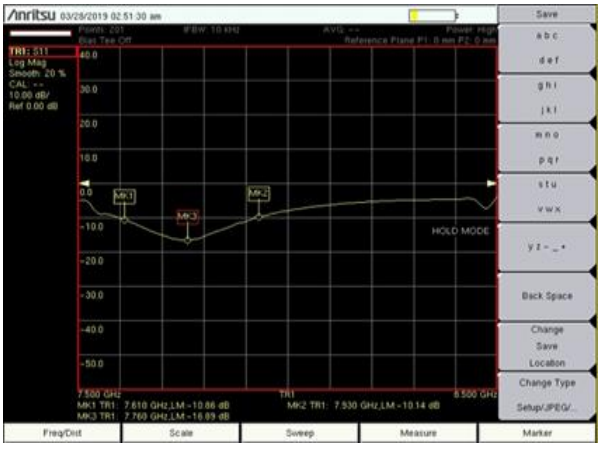


**Fig 11. Return loss of the fabricated antenna**

The Fabricated antenna is resonating in between 7.5GHz and 8.5GHz with the return loss of -10.14 dB at 8 GHz frequency for FR4 material which is very much best than the simulated return loss of -16.5dB.

## V. CONCLUSION

Energy harvesting technique is most widely used for many wireless applications and in this we have designed an elliptical shape patch antenna at a frequency of 8GHz using HFSS. Then it was combined with a matching network and a rectifier circuit using ADS software. The results from the antenna has high gain and high efficiency and they are discussed. Then the antenna is fabricated and tested using a network analyser and the results are compared with the simulated results.

## VI. ACKNOWLEDGEMENT

The authors sincerely thank Ms. V.P. Padma Priya, PG Scholar, KCG College of Technology, for her support extended in the simulation of the antenna

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