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Research Paper | Engineering

A Compact Rectenna for Harvesting the Electromagnetic Energy Associated to Wireless Communication System

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ABSTRACT

In recent trend Rectenna (Rectifier Antenna) have received a great deal of attention especially for the standards to mitigate worse environment condition. Rectenna is widely explored since it gives more benefit than the conventional antennas which supports multiple operation. A design, simulation and implementation of an efficient Rectenna will be proposed for energy harvesting. The antenna and its integrated rectifying circuitry for specific resonant frequency can produce dc power from received electromagnetic waves. 3D electromagnetic field solving software like – Computer Simulation Technique (CST) studio or National Instrument's Applied Wave Research (AWR) will be utilized for the simulation and optimization of the proposed Rectenna design structure. Radiation pattern and its parameters like – Gain, Directivity, etc. of Rectenna will be tested with the help of available compact range measurement facility and 2-D experiment results like – Return Loss, Voltage Standing Wave Ratio (VSWR), impedance, etc. will be measured using Standard Vector/Power Network Analyzers.

KEYWORDS : patch antenna, rectenna, energy harvesting, electromagnetic field.

INTRODUCTION

SINCE the last century, space solar power transmission (SPT) and microwave wireless power transmission (WPT) has become an interesting topic to been discussed as renewable energy in the future. WIRELESS power transmission has received special attention recently for the implementation of low-cost and low-power battery-less operated sensors [4]. Since ambient energy is available in many frequency bands, RF energy harvesters capable of operating in multiple bands are of great importance. Rectifying antenna or rectenna is one of the most important components in the application of SPT and WPT [1]. Nowadays, various approaches for designing rectennas have been considered in the literature including single-band operation [8], broadband approaches, and multiband designs [4]. Generally rectenna is a device that converts microwave or electromagnetic (RF) energy to direct current (DC) power. It is useful as the receiving terminal of a power transmission system where DC power needs to be delivered to a load through free space, where physical transmission lines are not feasible. It is also useful in applications where DC power needs to be distributed to a large number of load element in an array. The power distribution is achieved by the distributed nature of microwave energy in space, eliminating the need for a large number of physical interconnects to individual load elements. Rectenna was use as receiving terminal in ground to ground, ground to space and space to space transmission system.

The main important part in this project is an antenna. During the past years, different structures of antenna such as dipole, microstrip patch, loop, spiral, coplanar patch and parabolic have been used in designing the rectenna [2]–[8]. Rectifiers are generally made of diodes and matching elements. Rectifiers have different topologies depending on the configurations of diodes used for rectification purpose, which include single series, single shunt [9], [10], voltage doubler, and [11] and bridge type [12], [13]. The frequency selected for antenna is 5.8 GHz which means the antenna should be able to operate in that frequency. Frequency 5.8 GHz were selected as operating frequency of this rectenna because the probability to get high efficiency rectenna is high [3]. The second part in this project is to design the stub that act as filter to suppress harmonics signal. This part must be design to match the antenna and diode impedance, so that the rectenna could rectify effectively. Then the rectenna will convert the RF energy into DC power by using rectifier circuit.Rectifier circuit is consisting of diode and the load resistor for power measurement. This project will be focusing on the ability of rectenna to convert EM energy to DC power.

MICROSTRIP PATCH ANTENNA DESIGN

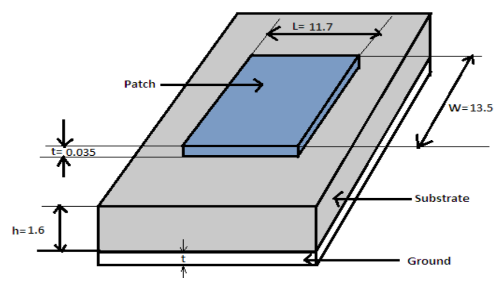

Fig. 1 Antenna geometrical configuration

The geometry of the proposed antenna along with its parameters is shown in Fig. 1. The antenna was initially designed and developed on 0.787-mm thick FR-4 substrate and fed by a coaxial probe which is operating at 5.8 GHz frequency.

Steps required for calculating antenna parameters:
Calculation of the width W of antenna:

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

f_r = resonant frequency

εr = Dielectric constant of the substrate

Calculation of Effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{-\frac{1}{2}}$$

Calculation of Effective Length (L_{eff}): The effective length is calculated from the known frequency to which antenna is to be designed and dielectric constant of material

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}}$$

Calculation of Length Extension (ΔL): The extension length due to fringing field effect in the radiating patch is calculated given by

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

Calculation of Actual Length (L): From the fringing length the actual length of the patch is calculated given by

$$L = L_{eff} - 2\Delta L$$

Antenna parameters are calculated from the given equations and they are as under.

Parameters	Values
f_r	5.8 GHz
W	13.5
L	11.7
h	1.6
t	0.035
ε_r	4.3
Dielectric substrate	FR-4

Table 1. Antenna parameter and its value

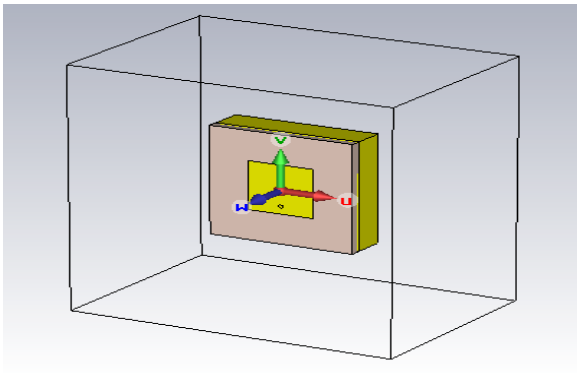

Fig. 2 CST view for proposed antenna

RECTENNA DESIGN

Rectenna is an important component for the energy harvesting. Rectenna consist of antenna and rectifier circuit which converts EM wave in DC power. We are using single diode and lumped element like register and capacitor for rectifier circuit. More specifically, a schematic representation of the circuit used for rectification is given in Fig. 3, it is a single diode half-wave rectifier.

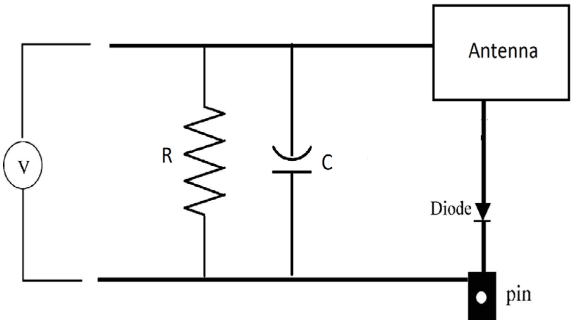

Fig. 3 schematic representation of the circuit used for rectification

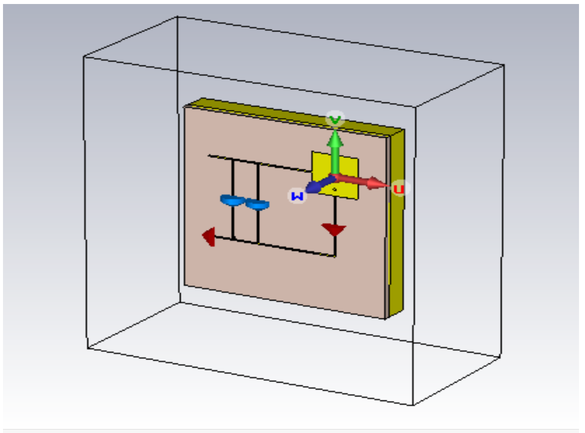

Fig. 4 CST view for proposed Rectenna

RESULTS

MICRO STRIP PATCH ANTENNA

We are using CST studio for the simulation of proposed antenna and rectenna design. Simulated results for simple antenna are as under. First we are calculating S-Parameter and VSWR for simple micro strip patch antenna. Simulated results for micro strip patch antenna are as under.

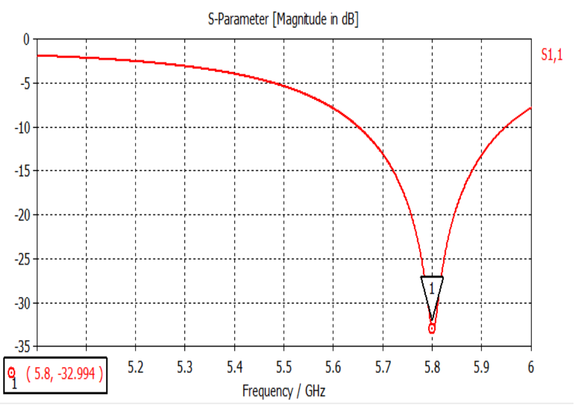

Fig. 5 S-Parameter

A representation of S-parameter vs. frequency , at resonant frequency 5.8 GHz, for simple micro strip patch antenna as shown in figure 5.For same VSWR representing in figure 6.

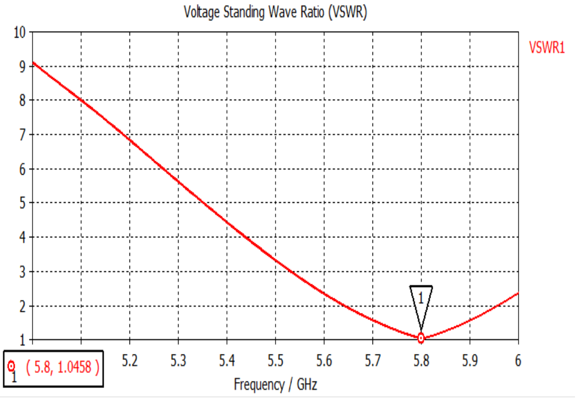

Fig. 6 VSWR

RECTENNA

After connecting a rectifier circuit to the antenna we get the simulated results in for the rectenna circuit are as under. Figure 7 representing the S-parameter at the resonant frequency 5.8GHz. In this figure green line represent S-parameter when diode in OFF condition and red line represent S-parameter when diode is in ON condition. VSWR for rectenna circuit is shown in figure 8.

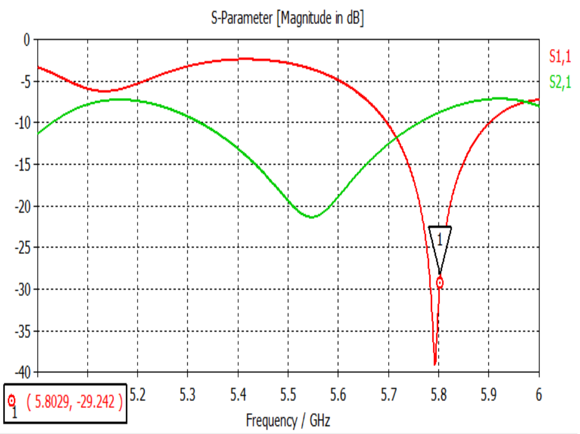

Fig. 7 S- Parameter for Proposed Rectenna

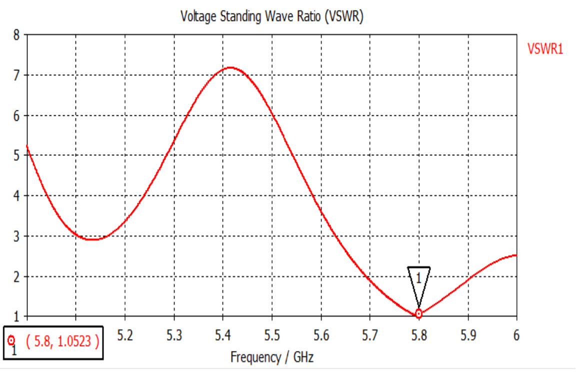

Fig. 8 VSWR for Proposed Rectenna

CONCLUSION

In this paper, the performance of a compact rectenna for the electromagnetic energy harvesting, in wireless applications, with better efficiency and performance has been described.

This paper describes the original work on designing a rectenna for energy harvesting. Rectenna is the device that uses to capture and convert microwave signal into DC power and it is use as receiving terminal. This project is undertaken as a solution to generate the power without using either electricity or solar because in some places, this two power source is not available due to some limitation. For example a network with large number of micro electronics devices they need battery or power supply but instead of this we can also use microwave or radio frequency to generate power. So, in this project we are design a 5.8 GHz rectenna to capture and convert microwave signal into DC power. Generally, rectenna consist of an antenna and rectifying circuit and both of them will determine the overall performance of rectenna. Rectenna was design by using CST microwave studio software and fabricated on FR-4 board because the printed rectenna is low cost and easy to manufacture. Measurement experiment is carried on by transmitting different input power by using Microstrip patch antenna and being measured at different load.

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