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Design of Multi Band Rectenna using Blank Box Optimization Technique

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Abstract- *As we all know that demand of energy is increasing day by day. We all are surrounded by the Radio Frequency waves, so the harvesting of radio waves for our energy requirements could be the alternative source of energy. Rectenna is a device that is used to convert RF Energy into DC power. Rectenna is designed using triangular micro strip patch antenna TMPA. The main motive behind this is to have battery free devices. This thing will also help us to protect our nature from harmful chemicals like cadmium, mercury etc. that are used in batteries This paper is concerned with the study design, analysis and fabrication of multi band Rectenna so that it can be used at various frequencies. We have used the blank box optimization technique in order to get enhanced bandwidth, gain, Return Loss and efficiency.*

Key words- *Rectenna, RF Energy, TMPA, DC Power.*

I. INTRODUCTION

Power transmission dates back to the early work of Hertz [1], He wasn't only the first who showed the propagation of electromagnetic waves in free space, he was also the first to experiment with parabolic reflectors at both the transmitter and receiver ends. In the recent years there has been very great demand of wireless power supply, so that we can cut the use of long and hassling cables, and overcome the problem of changing batteries again, so that the devices can work for a very long time without any interruption [1]. In this paper, we will focus on wireless power transfer via electromagnetic radiation, as opposed to inductive power transfer for example. The key component for this type of wireless power transfer is the Rectenna. The first energy transfer was demonstrated by Nikola Tesla in the early 1890's for the for the purpose of lighting applications and in this experiment most of the part of wireless power transfer (WPT) was occupied by the communication system in 20th century [2]. In the recent years the demand for wireless power transmission or RF energy harvesting has been increased due to its use in wide variety of applications. For all this purposes Rectenna is found to be one of the most important component to provide DC power in wireless sensors [3, 4]. The problem of wireless power transmission differs from that of wireless telecommunications, such as radio. In the latter, the proportion of energy received becomes critical only if it is too low for the signal to be distinguished from the background noise. With wireless power, efficiency is the more significant parameter. P. E. Glaser proposed the concept of solar power satellite system (SPSS) [5], and the first experimental microwave power transmission in space was carried out by Hiroshi Matsumoto's team in 1983 [4][5].

II. BASIC PRINCIPLE AND WORKING

The general setup of a rectenna is shown in Fig. 1. This setup is different from the setup proposed by Heikkinen, which has an impedance matching circuit between antenna and rectifying circuit. This matching circuit can be avoided when the antenna and rectifying circuit are designed such that they are already matched. For this purpose the behavior of the antenna and rectifying circuit have to be modeled at and around the operating frequency.

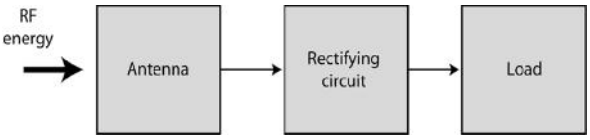

Fig.1 General Setup for Rectenna.

(A) RF-DC RECTIFICATION

The association of a receiving antenna and an RF to DC rectifier circuit is usually called a rectenna ("rectifying antenna"). Rectennas are built using diodes or diode-mounted transistors for rectifying the high frequency sine wave generated by the antenna into DC voltage. Diodes are characterized by a threshold voltage that has to be overcome in order to put them in a conductive state. When important incident power levels are available, diode threshold voltage is not an issue, because incident voltage amplitude is much higher than the threshold voltage [5]. In the case of low incident power (below 1 mW), loss in the diodes themselves become predominant. The choice was made to use zero bias Schottky diodes due to their low threshold (around 150 mV) and their low junction capacitance (0.18 pF) [6]. Working frequency is also an important parameter to consider when designing a rectenna. It isoften dictated by the desired application. At low frequencies (below 1 GHz), high gain antennas tend to be quite large. Increasing the frequency thus allows the use of more compact antennas. On the other hand, the amount of available power at a certain distance from an emitter is given by Friis equation:

PP

$$P_r = P_t . G_t . G_r . \left(\frac{\lambda}{4\pi R}\right)^2 \qquad (1)$$

where P_t is the power of the emitter ,G_t and G_r are the emitter and receiver antenna gain, respectively, λ is the wavelength used and R is the distance separating the emitter and the receiver. This means that available power at a certain distance from the emitter decreases as the frequency increases. Frequencies in the 1 GHz – 3 GHz range are considered to provide a good compromise between free-space attenuation and antenna dimensions.

(B) DESIGN OF RECTENNA

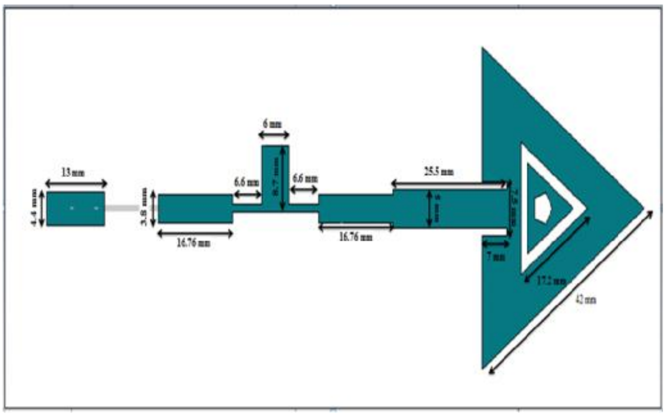

Fig.2- Block diagram showing dimensions of design of front view of Rectenna.

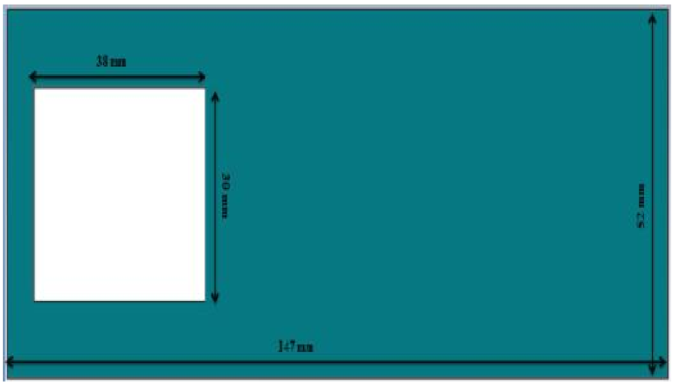

Fig.3- Block diagram showing dimensions of design of front view of Rectenna.

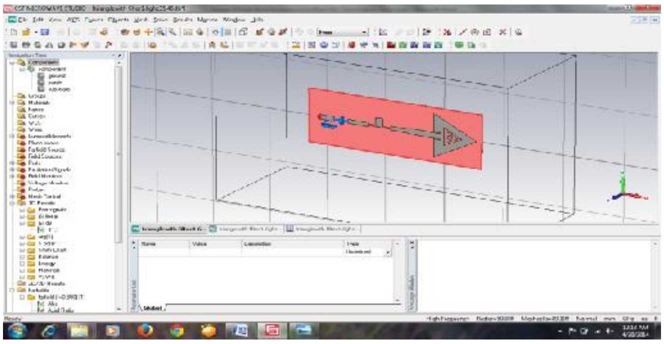

Fig.3- 3D view of Rectenna in CST Environment

III. RESULTS

Fig.5 is showing the graph of Return Loss vs Frequency. From the graph we can say that we are getting the four Frequency bands. The first frequency band is marked by Symbols 1 and 2, which is having the band width of 209.14 MHz, symbols 3 and 4 denote the frequency band of 232.44 MHz. symbols frequency. Symbols 5 and 6shows the frequency band of 360.6 MHz. Fig 7,8. Shows the 3D radiation pattern and efficiency of Rectenna at Frequencies 0.451 MHz and at 1.0512 MHz.

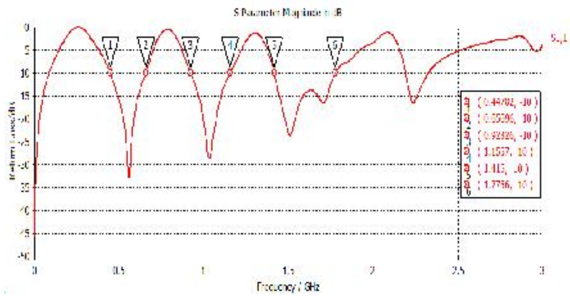

Fig.5-Graph showing relation between Return loss and Frequency.

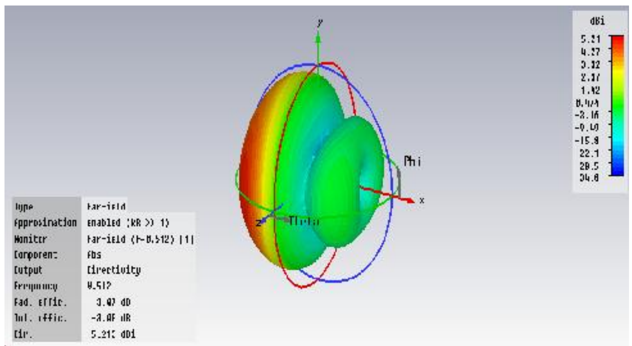

Fig.6- 3D Radiation Pattern at 0.512GHz

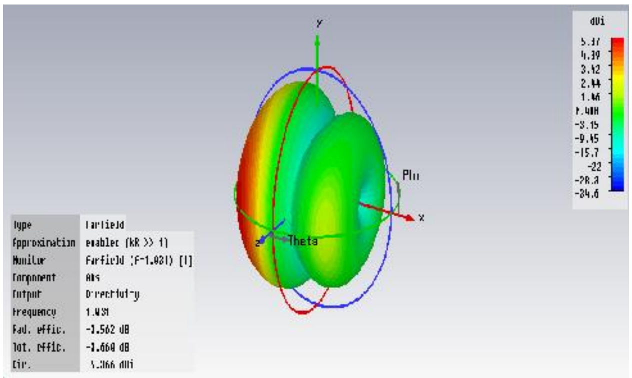

Fig.6- 3D Radiation Pattern at 1.031 GHz

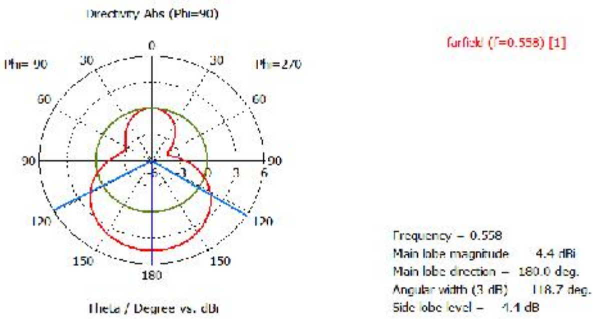

Fig.a.

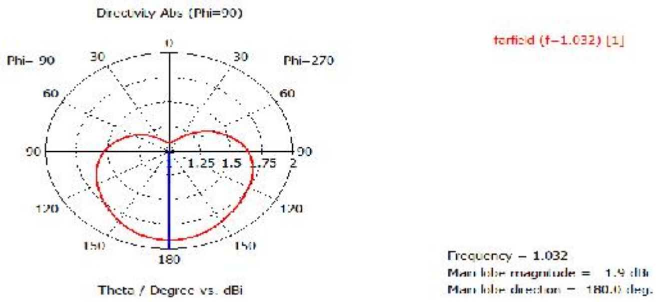

Fig.b.

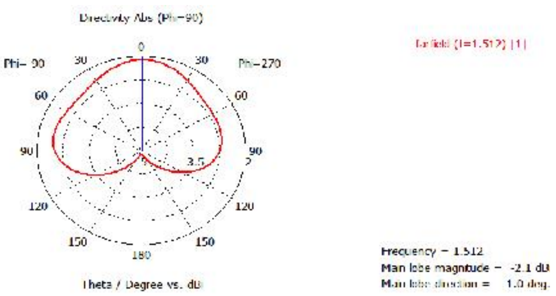

Fig.c.

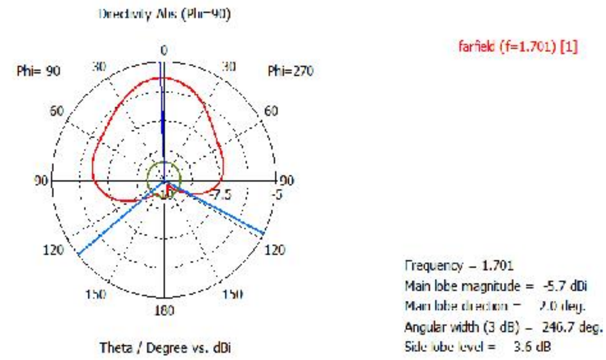

Fig.d.

Fig.7- Fig a,b,c,d Shows Polar plot at different frequencies.

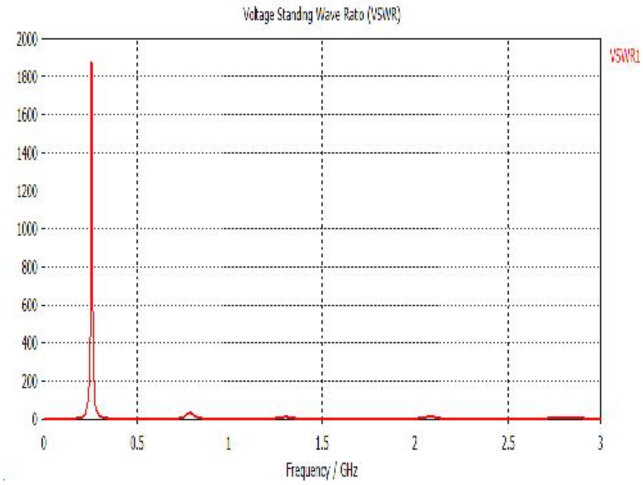

Fig.8- VSWR Plot

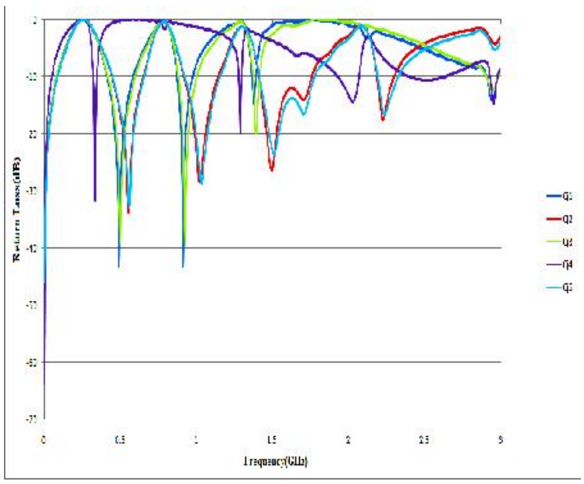

Fig.9- Variation in Return Loss with changes in Junction capacitances.

Table1. Values of capacitances

S. No.	Capacitance	Value of capacitance in Pf
1.	C_{j1}	0.02
2.	C_{j2}	0.2
3.	C_{j3}	2
4.	C_{j4}	20
5.	C_{j5}	200

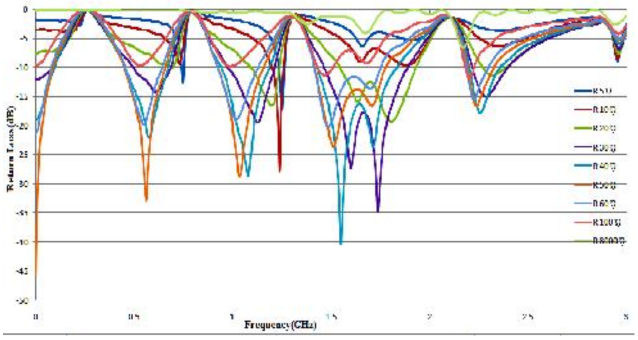

Fig.10- Variation in Return Loss vs Frequency with changes in Load Resistance.

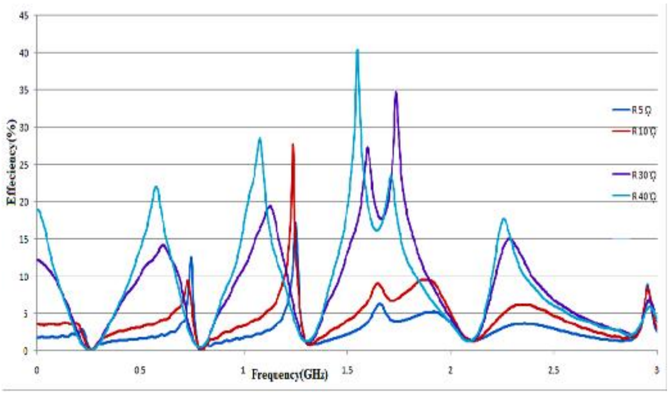

Fig.11- Efficiency vs Frequency plot.

From the above fig. 10 we can say that we get the optimum Return Loss at all four frequency bands at 50 ohm load resistance value. Either we too much decrease or increase the value of load resistance the performance of rectenaa decreases. Figure 11 shows the efficiency vs frequency plot, from the plot we can say that how the efficiency varies with frequency when the load on the Rectenna is varied, we are getting the maximum efficiency of 42% at 1.6GHz frequency with the load of 40 ohm.

IV. CONCLUSION

From the above results we can say that the amount of microwave power that the Rectenna can convert into DC power depends upon many factors. It depends upon the junction capacitance of diode, load that is provided by the user, we get the maximum efficiency when all these parameters are in proper arrangement. When we include the blank box at the back portion (ground) of Rectenna the efficiency of Rectenna is increased to 62%, and we also came to find that it can bear more load i.e. the efficiency of Rectenna jumps to 62 % with the load of 50 ohm applied to it.

V. FUTURE SCOPE

As in future we all know that there will be energy crises, so harvesting of energy from the available sources will be the most dominating area in research and development. Due to this reason Rectenna is catching the attention of many researchers. In future it may be commercially used for harvesting energy from the available sources like radio waves from satellite, cell phone, wi-fi etc.

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