DESIGN AND ANALYSIS OF RECTENNA FOR RF ENERGY HARVESTING

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Abstract

In this paper design and analysis of Rectenna for RF energy harvesting is proposed. The concept of RF energy harvesting is simply to utilize the microwave power available in our surroundings. The proposed Rectenna is designed and analyzed at 2.45 GHz frequency. The proposed design consists of Rectangular Microstrip Patch Antenna followed by Elliptical low pass filter. The proposed module of Rectenna gives -37 dB simulated return loss. Which shows good degree of design accuracy. The proposed design is designed and simulated on computer simulation technology microwave studio 2010.

Keywords: Rectanna, RF energy harvesting, computer simulation technology microwave studio, Rectangular microstrip patch antenna (RMPA), Elliptical low pass filter (LPF).

1. INTRODUCTION

The concept of Rectenna is simply to utilize the microwave power available in our surroundings effectively and efficiently. Now a days the microwave power is available mostly in all corners of world for some specific purpose but not get utilized fully. The RF energy harvesting is an effective and efficient utilization of surrounding microwave energy. The RF energy harvesting can be done using Rectenna which can be used to operate low power appliances and also for wireless mobile charging. The concept of wireless power transmission began with idea and demonstration by Nicola Tesla in 1899[1]. In early 1960s Brown invented Rectenna that directly converts microwave energy to DC energy [2]. Rectenna is a receiving rectifying antenna that receives microwave energy and converts it into DC energy using rectifier.

In this paper author proposed design and analysis of Rectenna at 2.45 GHz frequency. The Rectenna consist of a receiving antenna to receive microwave energy followed by low pass filter, impedance matching network and rectifier circuit. Low pass filter is used to filter out the harmonics generated by rectifier circuit. Impedance matching network is used to eliminate the power loss due to impedance mismatch between the low pass filter output and rectifier input using maximum power transmission theorem.

2. RECTENNA DESIGN

Figure 1 below shows the basic block of Rectenna. It consists of a receiving antenna followed by low pass filter, impedance matching network and rectifier circuit. Receiving antenna receives microwave energy and converts it into electrical energy (AC), low pass filter is used to suppress the harmonics generated by rectifier circuit that converts AC energy into DC energy by the process of rectification. Impedance matching network is used to minimize the impedance mismatch losses between low pass filter output and rectifier input.

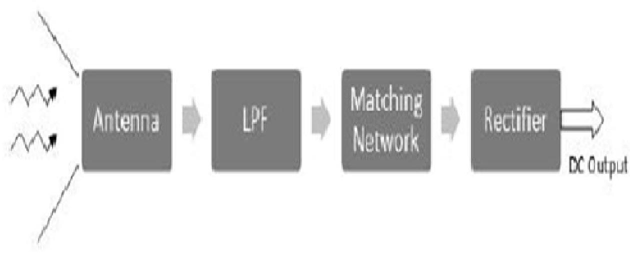

Figure1: Block diagram of Rectanna

FR4 (lossy) substrate is used for design of Rectenna having dielectric constant 4.3 and thickness of 1.6 mm.

2.1 Antenna design

Proposed design consist of rectangular microstrip patch antenna is used as receiving antenna because of its various advantage as low profile, small size, light weight. RMPA is designed and fabricated on FR4 (lossy) substrate. The calculated length and width of proposed antenna at 2.45 GHz [5] is L = 28.2 mm, W = 38 mm. Figure 2 shows the front view of RMPA and Figure 3(a) and Figure 3(b) Shows the fabricated structure of RMPA. Figure 4 and Figure 5 shows simulated the S parameter and directivity results of RMPA.

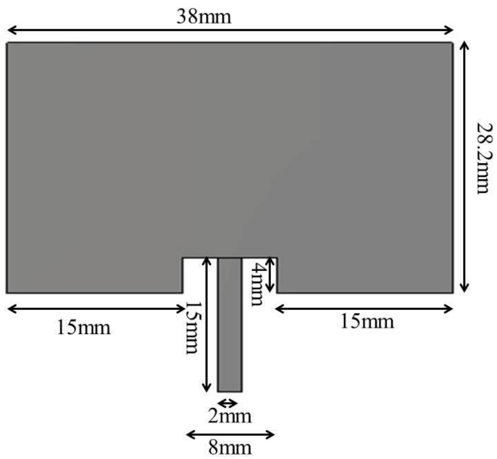

Figure2: Top view of RMPA

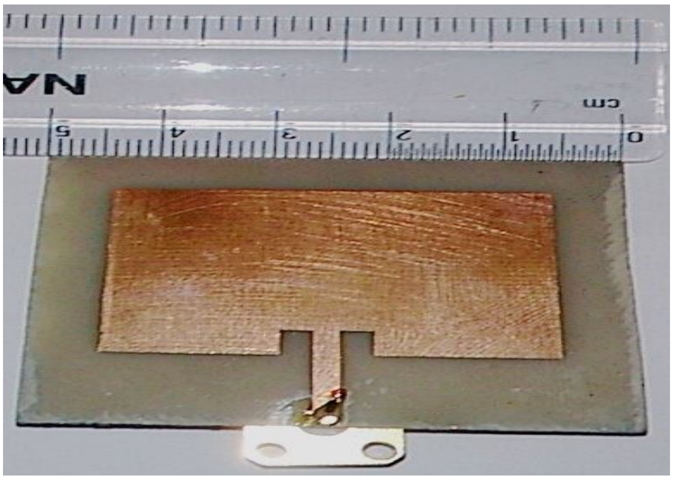

Figure3 (a): Fabricated structure of RMPA (patch view)

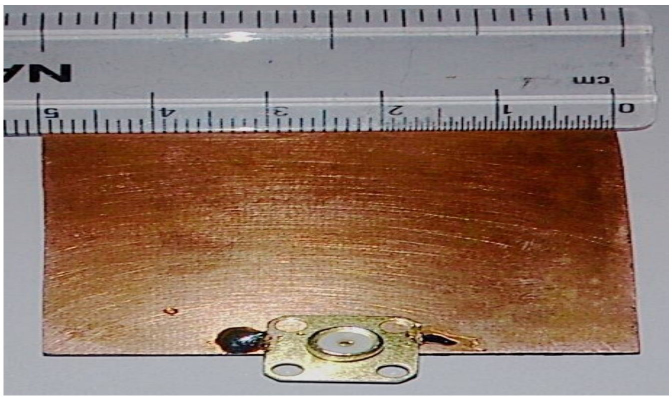

Figure3 (b): Fabricated structure of RMPA (ground view)

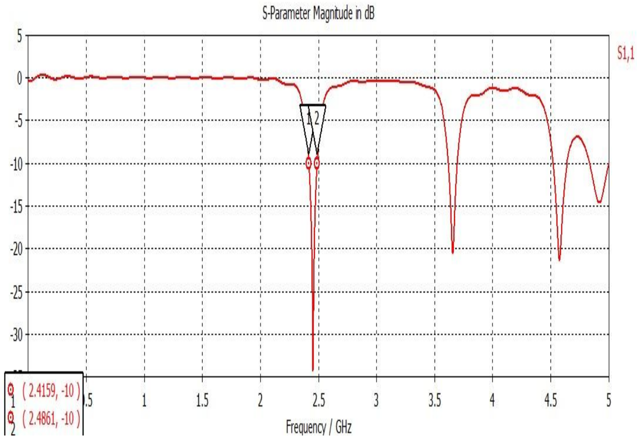

Figure4: Simulated S parameter of RMPA

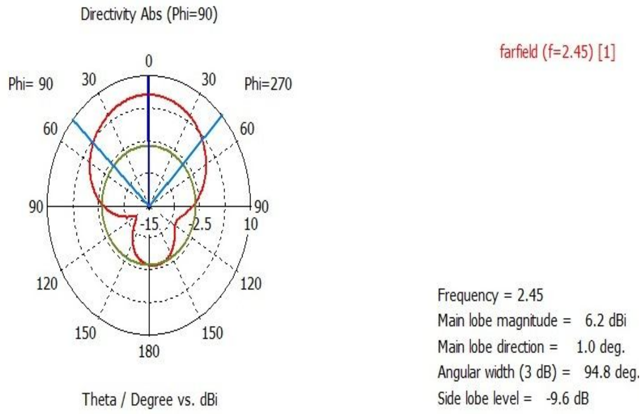

Figure5: Simulated Directivity of RMPA

2.2 Low Pass Filter Design

In the proposed module elliptical low pass filter is used to suppress the harmonics generated by the diode used in rectifier circuit. The proposed filter is designed on FR4 (lossy) substrate having dielectric constant 4.3 and height of dielectric substrate is 1.6 mm. The order of filter is seven having element values considerer for elliptic function low pass prototype filter[9]- source resistance $g_0 = g_8 = 1.0$, pass band ripple $L_{Ar} = 0.1$dB, minimum stop band attenuation $L_{As} = 66.7795$ dB, $g_1 = 1.1034$, $g_2 = 1.3189$, $g'_2 = 0.0940$, $g_3 = 1.8177$, $g_4 = 1.2583$, $g'_4 = 0.2770$, $g_5 = 1.5856$, $g_6 = 0.8983$, $g'_6 =.0.2770$, $g_7 = 0.7755$.

Where g_i represent inductance of the inductor (for i = 1 to 7) and g'_i represent capacitance of the capacitor (for i = 2, 4, 6). Figure 6 shows the top view with calculated values for elliptical low pass filter at 2.8 GHz frequency. Figure 7(a) and Figure 7(b) shows the fabricated structure and Figure 8 shows the simulated S parameter of proposed elliptical low pass filter.

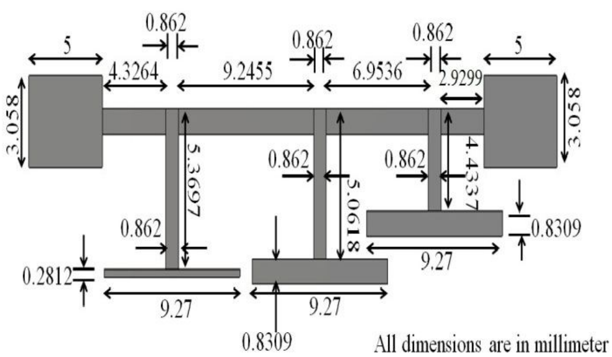

Figure6: Top view of elliptical LPF

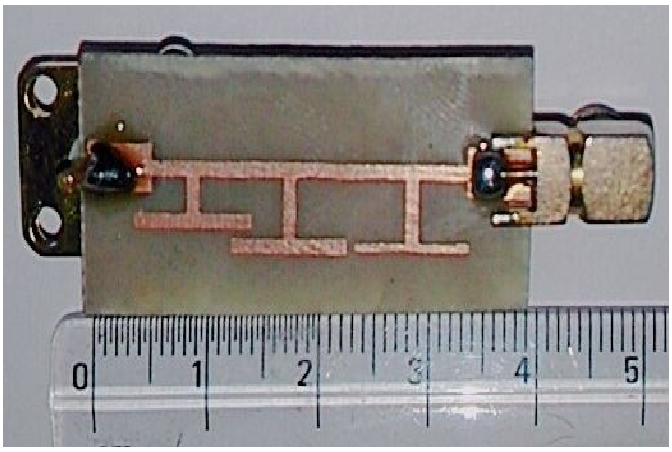

Figure7 (a): Fabricated structure of elliptical LPF (patch view)

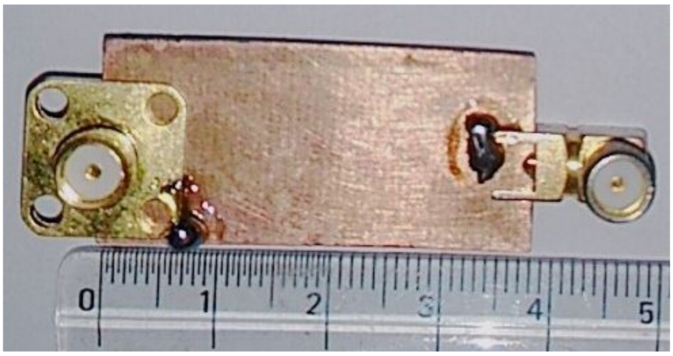

Figure7 (b): Fabricated structure of elliptical LPF (ground view)

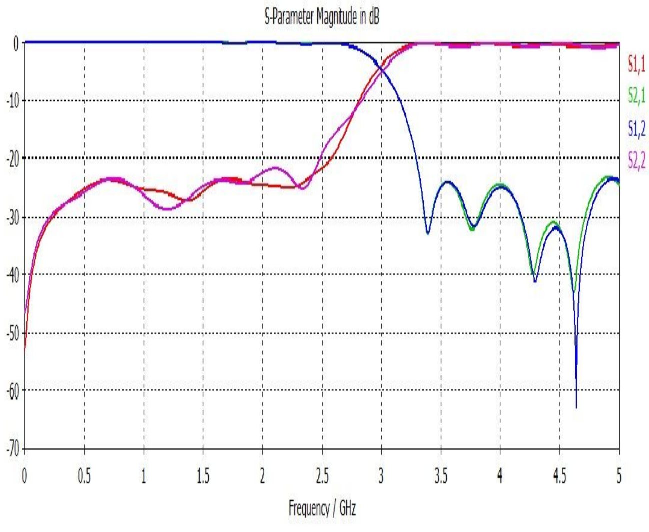

Figure8: Simulated S parameter of elliptical LPF

2.3 Combined structure of RMPA and Elliptical LPF

Combined structure after joining output port of RMPA to the input port of elliptical LPF is designed on FR4 (lossy) substrate having the dielectric constant 4.3 and height of dielectric is 1.6 mm. Figure 9 shows the top view of combined structure on CST 2010 software and figure 10(a) and figure 10(b) shows the fabricated structure. Figure 11 and Figure 12 shows the simulated S parameter and directivity of combined structure.

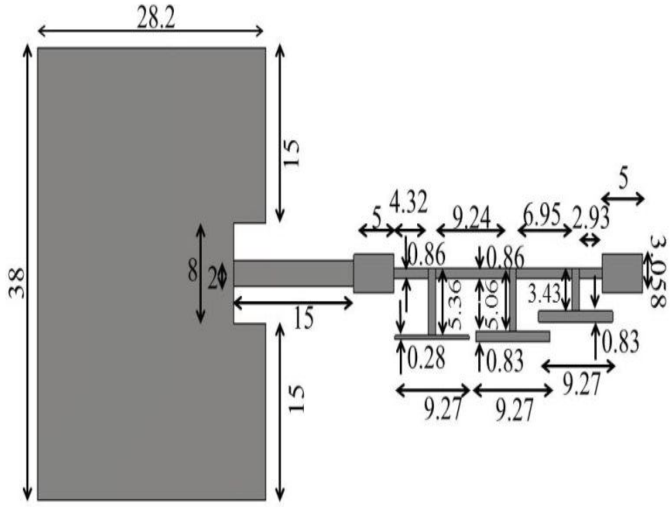

Figure 9: Top view of combined structure

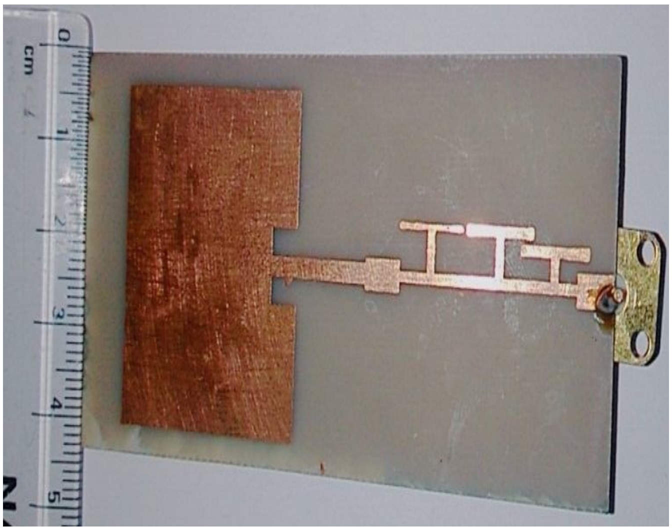

Figure10 (a): Fabricated combined structure (patch view)

Figure10 (b): Fabricated combined structure (ground view)

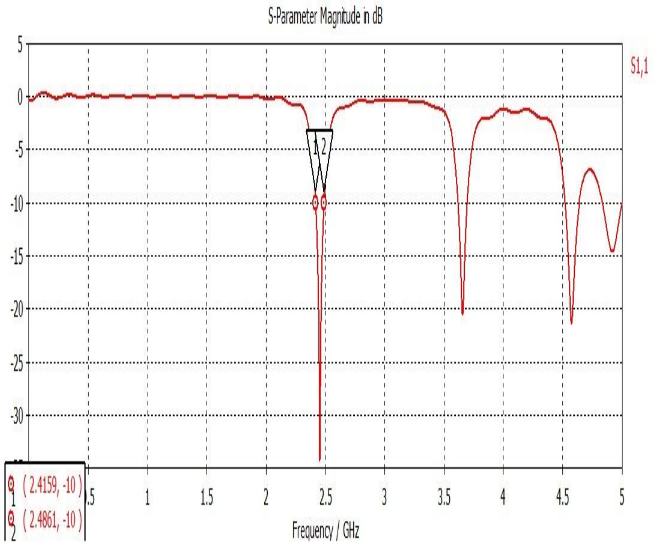

Figure11: Simulated S parameter of combined structure

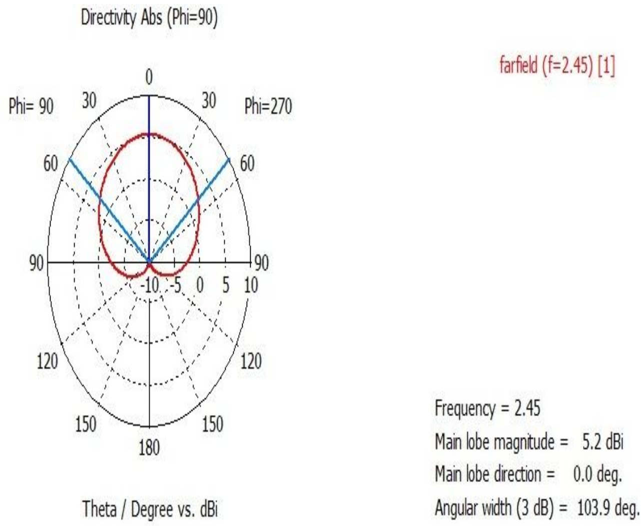

Figure12: Simulated directivity of combined structure

3. Conclusion

This paper presents the design and analysis of rectenna. The proposed module is designed and analysed on CST 2010 at 2.45 GHz frequency. The proposed module is also fabricated. The RMPA is designed for a lesser return loss of -34 dB to have more efficient rectenna. The rectenna is designed with a high order (seventh order) elliptical LPF. The combined structure have -37 dB return loss. Proposed module receive RF energy at 2.45 GHz and filter removes higher order harmonics, then this power is fed to rectifying circuit with the help of impedence matching circuit which convert AC power into DC power.

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