DESIGN OF LOW COST RECTENNA FOR WIRELESS ENERGY HARVESTING

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ABSTRACT:

In the wireless world, wireless power move is one of the emerging technologies. Energy harvesting is the reason behind the success of wireless sensor networks. Though wireless sensor networks find lots of applications in agriculture, an industry etc, one of the major constraints is its power consumption. The physical model comprises of antenna, a Schottky diode,a matching microstrip line, and an output low-pass filters are designed using lumped components was designed and developed using the software Advanced Design System (ADS). ADS software for designing microwave electronic circuits. Schottky diode (HSMS-2820) is used for rectification. The circuit is designed using FR4 substrate h=1.6mm and εr = 4.6 having the fabricated dimensions of 285mm x 90mm. The return loss output of the Rectenna is measured as -66 with a load resistance of 500 Ω.

Key words : Rectenna ,wireless energy Harvesting, Ultra Wide band.

I. INTRODUCTION

RF energy harvesting system acting important role in gathering clean energy from nearby environment. The issues linked to self-configuration, power management, and reliability must be addressed, effectively. This paper addresses the power management issues by incorporating energy harvesting technology for the SOs in the next Wireless application. The solution for this problem can be either power consumption decrease or external power supply by means of energy harvesting. A lot of energy is wasted in the power conversion process of Powering an Empty Chest Freezer, Washing Clothes in Hot Water ,Almost 90 precent of a washing machine's energy is useless heating water. You can hack energy use in half by switching from hot to warm water, and reduce it even further by using cold water. This Problem overcome by energy harvesting that is abundantely available in the form of solar (100mW/cm^2), thermal (60 µW/cm^2), vibration (200 µW/cm^2) and radio frequency (1 µW/cm^2)[6]. The physical model comprises of antenna, a Schottky diode,a matching microstrip line, and an output low-pass filters. Apart from RF energy, most of the other sources are environment reliant that makes this technology more useful in critical applications such as environmental monitoring, healthcare, and defense etc. [7]. The design parameters of the antenna such as the width and length of the patch are based on the operating frequency of 2.4 GHz are calculated using Equation in [9].To obtain the maximum energy in a wide range of frequencies, wideband and the compact antenna is desired to power up small handheld devices i.e. cell phones, tablets, electronic watches and other smart devices. It is desired that the RF systems for energy harvesting should be able to cover most of the telecommunication bands like 2.4 GHz, 5.1 GHz, 5.8GHz (Bluetooth/Wi-Fi), 2.3 GHz, 2.5 GHz, 3.5 GHz,5 GHz (WiMAX), 3.4-3.6 GHz etc. [10]. Apart from the antenna, the rectifier circuit with high conversion efficiency characteristics is needed that can effectively function on most of the frequency bands of 2G/3G/4G networks, Wi-Fi and TV/radio broadcasting.

II. RECTENNA DESIGN

The block diagram of the rectenna circuit is shown in Fig. 1. It can be seen in Fig. 1 that the rectenna circuit comprises of an antenna, a BPF, matching circuit, a rectifier circuit, and a LPF. Each module is matched to the next module using stubs for maximum power transfer [17].In order to fulfill the rectenna design requirements, the first step is to design the antenna. Here, an MPA is prefer and used which serve as a promising solution for these requirements as they are small, low-profile and easy-to-fabricate whereas their shortcomings such as narrow bandwidth and low-gain characteristics can be improved by using different techniques [18-22]. A typical MPA consists of a radiating patch and a ground plane. The radiating patch is characterized by its relative permittivity and height [17]. The fringing-field effect between the ground plane and the radiating patch causes the patch antenna to emit at a single resonant frequency [17]. For the radiating patch to resonate at multiple frequencies, slots and slits can be introduced in the design which alters the current path on the patch [19-22]. The low-cost FR4 substrate is used here with height (h), dielectric constant ($\mathcal{E}_r$), and loss tangent (δ) of 1.6mm, 4.6 and 0.019, respectively.

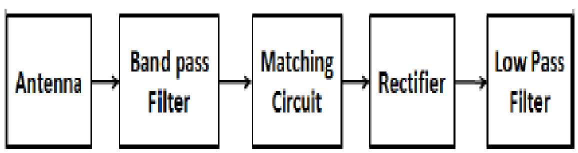

Fig 1 : Block diagram of the rectenna circuit

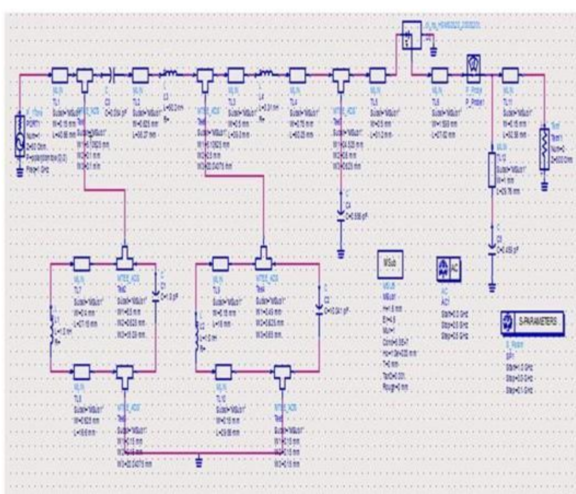

Fig 2: Schematic of diode rectifying circuit

Low pass filtering is the last step in designing the rectenna circuit as it smoothes the signal and removes any noise present.

All the individual modules of the rectenna circuit are then connected together using a matching circuit for maximum power transfer. Hence, input and output impedances of all the modules are measured to calculate the length and width of the TLs for maximum power transfer between the modules.

It can be seen from the S_{11} plot that the simulated antenna is resonating at 2.4GHz and showing an acceptable bandwidth of 25MHz.

$$C = \frac{1}{2\Pi f_c R} \qquad (1)$$

Freq =2.4 GHz

dB(S(1,1))=-32.415

M1

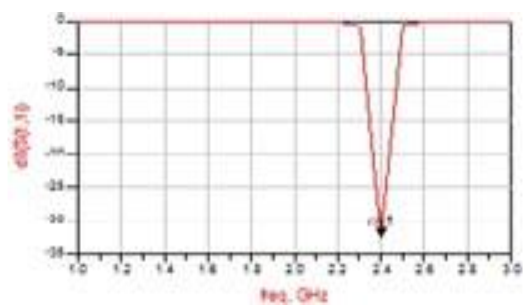

Figure 3 : Simulation result for S11 parameter of microstrip patch rectenna

This simulation goes -32.415 dB on frequency 2.4GHZ.

The Termination is connected to the output port ,in Which measured power losses is predicted to be -32.415 and the frequency corresponds to be 2.4 GHz. While on connecting load impedence, the resultant power losses , gets reduced to about -66.468 and frequency 2.236 GHz respectively. Hence, this is vital advantage.

BPF	Calculated	Implemented
L_1	50.2nH	50nH
$2L_2$	424pH	400pH
C_1	0.08pF	0.1pF
$C_2/2$	10.04pF	10pF

Matching circuit	Calculated	Implemented
L	3.3nH	3.5nH
C	0.6pF	0.55pF

LPF	Calculated	Implemented
C	0.5pF	0.45pF

Table I : calculated And Tuned Component Values of The rectenna Circuit

The rectenna design contains two main parts such as the receiving Antenna and the rectifier. The rectenna circuit comprises of a microstrip patch antenna (MPA), a filter, rectifier and a load. The MPA is designed using the low-cost flame resistant (FR4) substrate.

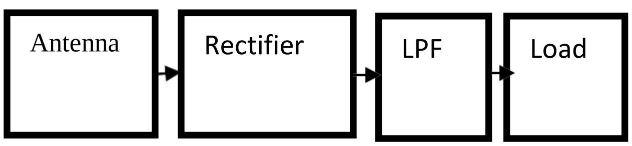

Figure 4: Block Diagram of Energy Harvesting System

The measured MPA bandwidth is found in good agreement with the simulated one. Lumped components are used to implement the and a low-pass filter (LPF) operating at the 2.4GHz band. A schottky diode is used to execute the rectifier circuit due to its high-speed switching at higher frequencies and low voltage drop characteristics. Transmission-lines and stubs are used for matching and maximum power transfer. Load impedence, inherent power losses in rectenna and non-linearity of the rectifier with corresponding frequencies are major challenges for state of the art rectenna design.The energy harvester is designed and simulated using Agilent advanced design system (ADS) Momentum—a simulator that works on full-wave analysis method-of-moment (MoM) technique [17,25].

The receiving antenna is a Microstrip Patch antenna and was Printed on FR4 substrate with permittivity of ξr =4.3 and thickness (h) of 1.6 mm. Microstrip feed lines with thickness of 0.035 mm was used to feed the antenna. The rectifier circuit was designed using Agilent ADS 2009 simulation software. The rectifier consists of two tapered microstrip lines, a Schottky diode,a λ/4 microstrip line,a matching microstrip line, and an output low-pass filters.

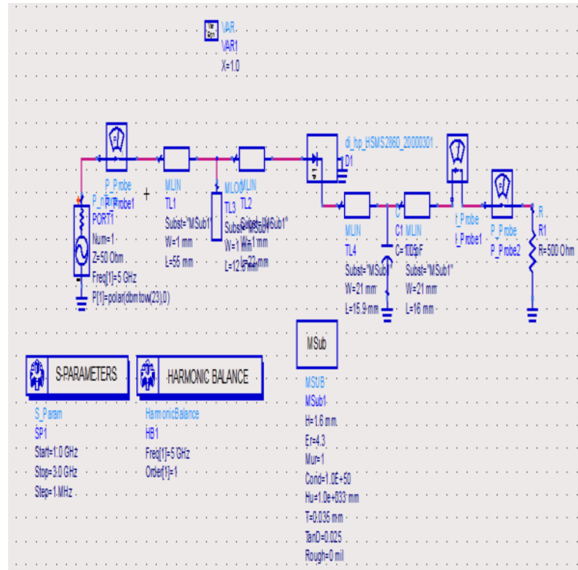

Figure5 : Schematic of diode rectifying circuit

III. SIMULATED RESULTS :

The Proposed Microstip Patch antenna was simulated in ADS Microwave using Time domain solver. The antenna 2.23 GHz is Shown in Fig. 2.

Freq =2.23 GHz

dB(S(1,1)) =-66.468

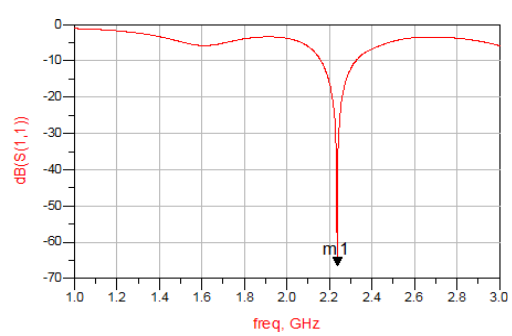

Figure 6 : Return loss of the Antenna

Fig. 5shows the simulated return loss results of the Antenna .As it can be seen from Fig.5, the antenna has an operating frequency of 2.23 GHz with a simulated return loss of -66.468 dB.

LOAD	RETURN LOSS
100Ω	-37 dB
200Ω	-42 dB
300Ω	-48 dB
400Ω	-53 dB
500Ω	-66 dB

Table 1: Tabulation determined for Load and Return loss

The different load resistance of 100Ω, 200Ω, 300 Ω, 400Ω, 500Ω and are simulated for maximum *Vout*. It is noted that at 500Ω, a return loss is calculated with better at 2.3 GHz band. Final rectenna measurements have been carried out by selecting physical components ranging from 500Ω.

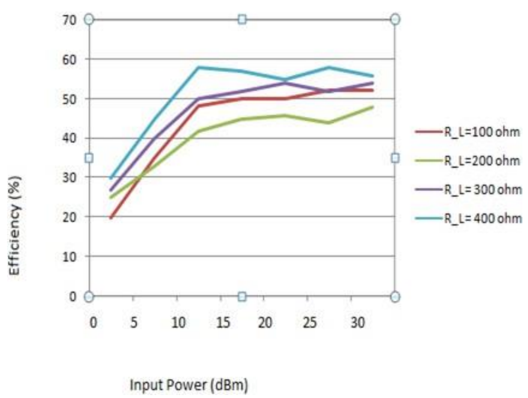

Figure 6 :Simulated DC voltage at different load resistance and input power

Frequency (GHz)	Antenna Size (mmxmm)	Return loss	Reference
2.4	30X 18	-40	[1] 2018
1.8	98X56	-25	[18] 2018
1.9	70X66	-20	[19] 2018
2.4	285X90	-32	[2] 2018
2.3	30X18	-66	Proposed work

The performance of the proposed rectifier circuit was analyzed and optimized by using commercially available software Advance Design System (ADS). The simulation results of DC voltage as a function of input power of the proposed rectifier circuit is shown in Fig. 5. From the DC voltage plot, it can be observed that the DC voltage increases dramatically when the input power is increases as well as load resistance. The conversion efficiency is simulated with respect to the rectifier circuit load at range of 0 dBm to 30 dBm of the input power as shown in Fig. 6. The highest conversion efficiency of 59.35% is reached at 30dBm of input power for the load of 200Ω. The efficiency increases gradually with the input power.

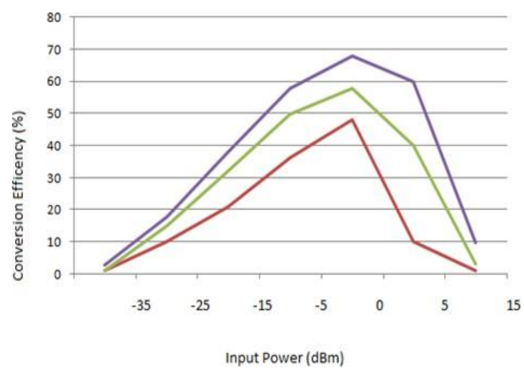

Fig7: Simulated and measured conversion efficiencies at different load resistance

Simulated conversion efficiency as a function of input power for 5 KΩ, 30 KΩ, and 50 KΩ is depicted in Fig. 5 . It is clear from the graph that the efficiency is low at low input power levels as well as with the increase of RF input signal power. Below 52% conversion efficiency is observed for -10dBm input power, while a peak conversion efficiency of75.5% is found at 5 dBm.

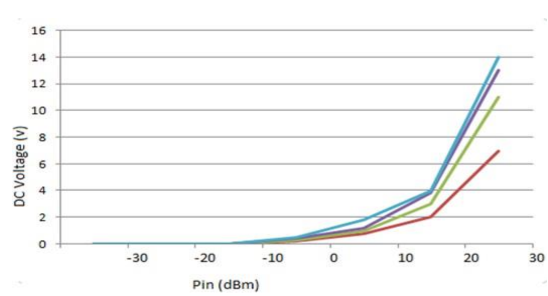

Fig 8: Measured and simulated conversion efficiencies for 2.3 GHz frequency levels.

IV .CONCLUSION

Rectenna design is investigated as wireless energy harvesting device operating at 2.3 GHz. Microstrip patch antenna and rectifier circuit are designed. The simulated characteristics of the antenna are analysed as well. The Antenna return loss is also analysed. Good agreement the simulated characteristics are obtained.

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