Antenna with Indirect coupling For Wireless Applications

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Abstract*—A planar aperture coupled microstrip antenna has been proposed for WLAN application 2.45 GHz band which can be used for Radio frequency (RF) harvesting. The proposed antenna consists of a two substrate layer of Duroid, rectangular hole at the ground and a square patch. The antenna resonats at 2.40 GHz will a fairly good return loss of -40 dB. The antenna gain at 2.40 GHz is 5.3 dBi.The total volume of the antenna is found to be 75 cm^3.

Keywords*—Radio Frequency (RF) harvesting, aperture coupling, aperture coupled rectangular patch microstrip antenna (ACRPMA)

I. Introduction

RF harvesting is basically the conversion of Electromagnetic waves in to electrical energy. The produced electrical energy can be utilized in many ways. People have already developed such rectenna (Rectifier + Antenna) and these systems can be used for purposes like in Bio-medical operations, structural health monitoring and virtual battery [7-11]. Walid Haboubi [et al] have proposed a dual circular polarized rectenna at ISM band which is complex in design [12]. T.M. Chiam [et al] have presented 5.8GHz polarized rectenna using Schottky diode, however the measured S11 parameter is only -10.3 dB and subsequently an array having S11 parameter of -20.3 db is designed [13]. Md. Saad-Bin-Alam has designed a multiband antenna resonating at 2.4 and 5.8 GHz having gain 2.25 and 4.3dBi. Gianfranco Andia Vera has discussed a rectenna for Electromagnetic scavenging for 2.45 GHz in which aperture coupling is used [14]. In this work a square patch is used with a cross shaped slots in it. The height of the foam used in it is 6mm which increases the volume of the antenna to a large scale. This paper presents a low volume aperture coupled antenna having a gain of 5.3dBi for RF harvesting for WLAN application resonating at a frequency of 2.4 GHz

II. System Block Diagram

Traditionally, the patch antenna is apt for narrow bandwidth applications. The challenge here is to enhance bandwidth of the patch antenna energy harvesting environment. The antenna design required to look into the permittivity or dielectric constant of the substrate, width, length of the patch antenna and the ground plane. Ideally the permittivity should vary between 2.2 to 12. Higher the permittivity higher is the bandwidth but more are the surface losses, whereas lower the permittivity lesser is the bandwidth. Moreover, the substrate should also be easily available in the market. The permittivity of the substrate plays a major role in the overall performance of the antenna. It affects the width, the characteristic impedance, the length and therefore the resonant frequency that resulting to reduce the transmission efficiency. One of the best methods to enhance the bandwidth is aperture coupled microstrip patch antenna.

Aperture coupling is an indirect method of feeding the resonant patch with the radiating microstrip patch element etched on the top of the antenna substrate, and the microstrip feed line etched on the bottom of the feed substrate [1]. The energy of the strip line is coupled via the opening (slot) in the ground plane, that excites the patch. The aperture is usually centered with respect to the patch where the patch has its maximum magnetic field for maximum coupling, it has been suggested that a rectangular slot parallel to the two radiating edges should be used. Two very similar coupling mechanisms take place, one between the feed line and the slot and another between the slot and the patch. The first aperture coupled microstrip antenna was introduced in 1985 by D M Pozar [1]. The antenna consists of two substrates bonded together, with a ground plane in between [2-4]. The radiating patch is printed on the top (antenna) substrate; while a microstrip feed line is printed on the bottom (feed) substrate. A small non resonant aperture in the ground plane couples the patch to the feed line. The bandwidth is essentially that of the patch antenna itself, and is not affected by the aperture coupling mechanism.

Antenna receives the EM waves and converts it to electrical quantity. Together the antenna, matching circuit and RF-DC conversion is called as the rectifier antenna or rectenna. The output DC level of the rectenna can be enhanced with the help of DC-DC converter. It may be a voltage doublers, or multistage voltage multiplier. The DC obtained can also be used to charge a circuit or can be stored to a battery. The block diagram of the RF harvesting is shown in fig. 1.

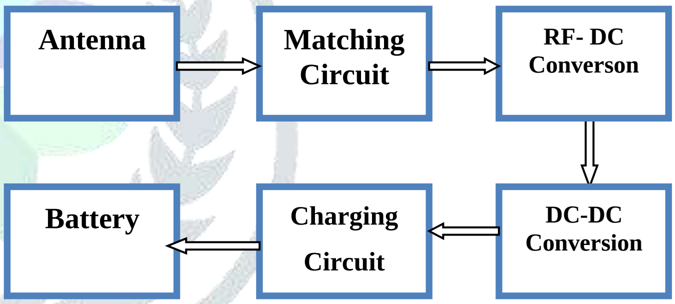

Figure 1: Block diagram of RF harvesting

One of the useful features of the aperture coupled microstrip antenna is that it can provide substantially improved impedance bandwidths [1]. A single band aperture coupled rectangular patch microstrip antenna (ACRPMA) is designed for the WLAN application (2.40-2.48) GHz range with centre frequency at 2.44 GHz. The dimensions of the patch were calculated for the WLAN applications as per the equations given in [2]. These dimensions were optimized to get the desired response. The dimensional diagram of the ACRMPA is shown in the fig. 2.

The figure 3 shows the front view of the designed antenna.

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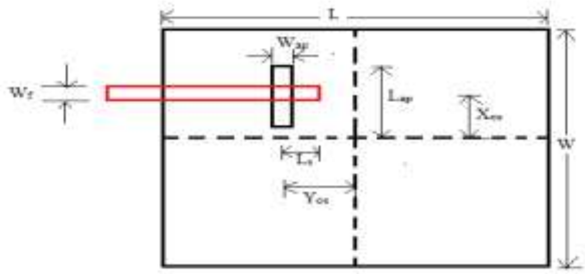

Figure 2:-Dimensional diagram of the Patch

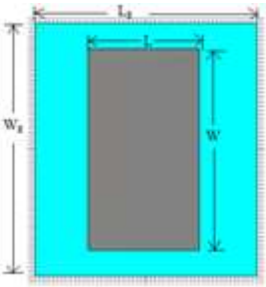

Figure 3:- Front view of the designed antenna

Design Equations:- The dimensions of the rectangular patch antenna are calculated by the following design equations.

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\epsilon r+1}} \qquad \text{--- (1)}$$

For the given frequency of operations, the width of the pacth antenna can be calculated by equation 1. Also the effective dielectric constant is calculated pby the equation 2.

$$\epsilon\, reff = \frac{\epsilon r+1}{2} + \frac{\epsilon r-1}{2}\left[1+12\frac{h}{W}\right]^{-.5} \text{--- (2)}$$

Due to the fringing effect, there is an increase in the effective length of the patch. This is calculated by the equation 3.

$$\Delta L = 0.412h\frac{(\epsilon reff+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon reff-0.258)\left(\frac{W}{h}+0.8\right)} \qquad \text{--- (3)}$$

Now the net length of the patch is calculated by the formula

$$Leff = L + 2\Delta L \qquad \text{--- (4)}$$

The table 1 shows the various dimensions that calculated & taken for the design of the single band antenna. However the for the optimized antenna for apertures coupling, using parameters sweep option in CST microwave studio the final value of the antenna are taken.

Table I

Parameter	Dimension of Single band antenna(in mm)
Length of patch (L)	25
Width of patch(W)	46
Length of feed(L_f)	23.5
Width of feed (W_f)	6
Length of Aperture(L_{ap})	30
Width of Aperture(W_{ap})	3
Length of Stub(L_s)	4.5
Offset in negative Y-direction(Y_{os})	6
Offset in X-direction (X_{os})	0
Height of Antenna and Feed substrate(H)	2.4
Resonate frequency(F_r)	2.40GHz
Dielectric Constant of the Antenna and Feed Substrate(ε_r)	2.2

III. Simulation Results

The figure 4 shows the S-parameter of the antenna where it depicted that the S11 is well below -10 db resonating at 2.4 GHz. At the frequency 2.4GHz, the antenna shows a maximum coupling and hence radiates the complete energy from it. Figure 5 shows that the gain of the antenna is fairly well above 5 dBi. For far field radiations, the absolute radiation efficiency of the antenna is 0.8141 db.

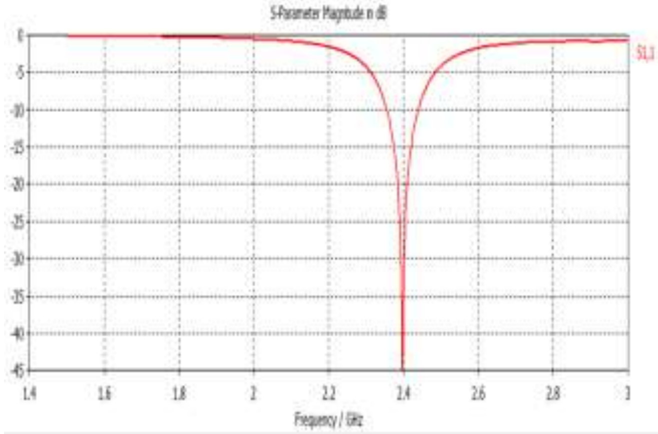

Figure 4: S- parameter of the designed antenna

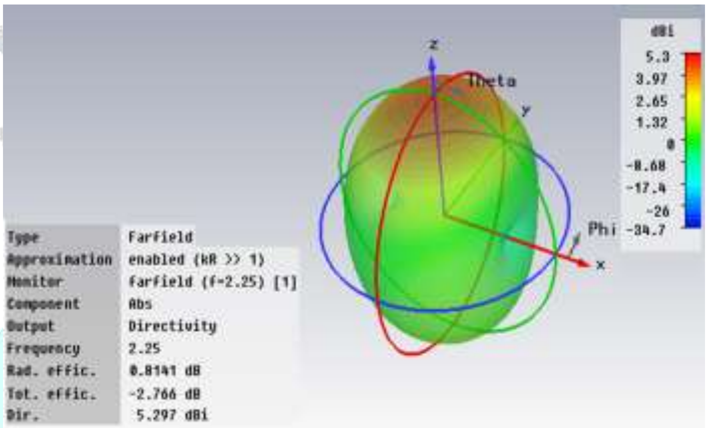

Figure 5: Radiation pattern of the antenna

Figure 6 shows the smith chart of the designed antenna which shows that the antenna matches at an impedance of 74.38 ohm.

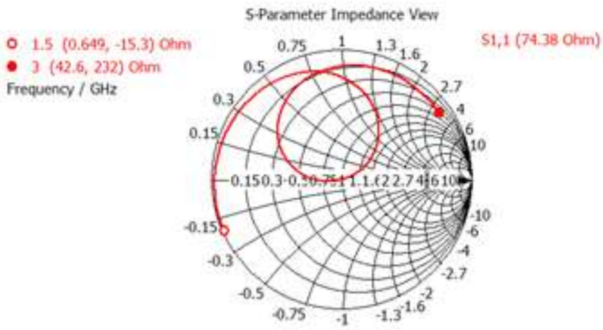

Figure 6: Smith Chart of the antenna.

IV. Conclusion

The aperture coupled antenna simulated has a gain of 5 dbi. Moreover for WLAN application large volume of the antenna is not the issue so aperture coupled antenna having inherently large bandwidth is more suitable. So the proposed antenna can be used for the RF harvesting in WLAN frequency range when it is used for receiving the waves.

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