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A Dual Band Microstrip Patch Antenna for RF Energy Harvesting

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***Abstract* – A dual band inset fed microstrip patch antenna designed for 2.35 GHz and 3.7 GHz Wi-Fi band applications is presented. The designed antenna has a rectangular patch with inset feed which is mounted on a FR4 substrate. The patch dimension, positioning and dimensions of the feed are determined by standard formulae. The antenna proposed performs well both in Return loss and VSWR. Return loss of -23.23 dB and -21.16 dB, VSWR of 1.20 and 1.56 were achieved for 2.35GHz and 3.7 GHz respectively. Simulation based techniques of HFSS were used to optimize the results. The simplicity in the geometry of the designed receiver antenna is attractive for its use in Radio Frequency Energy harvesting(RFEH) System.**

Keywords—Dual band antenna, inset fed, RF Energy Harvesting, WiFi band, WiMAX band, HFSS.

I. INTRODUCTION

In recent times, the size and cost factors are dominant in the wireless communications field. The microstrip patch antenna has upper hand compared to other antennas in this field and also provides planar and compact configurations. It has the ability to work for high frequency applications. The antenna design given has a lot of applications in mobile communication, Wi-Fi, WiMAX, Intelligent Transportation System and RF energy harvesting systems. This antenna operates for 2.35GHz and 3.7GHz frequency bands and can work on either of these frequencies one at a time or both frequencies simultaneously.

RFEH system can be proposed for ambient energy harvesting. Fig. 1 gives the block diagram representation of RFEH system. The system captures RF energy from various sources using a receiving antenna and then converts it into DC power which is stored in a battery. The stored DC power can be used to energize sensor nodes in WSN applications. It also helps in replacing the battery-operated devices like medical implants so that the implants can be energized with power whenever required rather than relying on batteries whose durability is limited. Two most common frequency bands used are 2.3-2.4 GHZ and 3.6-3.8 GHz. The 3.6-3.8 GHz band has a higher frequency and a smaller range. The 2.3-2.4 GHz inversely has lower frequency which allows the antenna to cover larger distances. A dual band receiving antenna can use both frequencies at once or switch between the two frequencies depending on which option provides stronger connection in the given area.

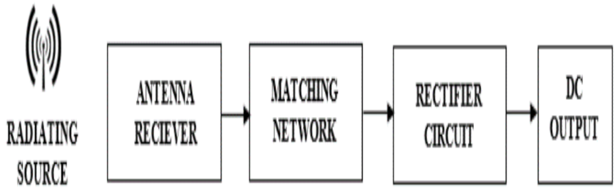

Fig. 1: Block diagram for RFEH System

II. LITERATURE SURVEY

Enormous amount of work has been carried out on RFEH system with various types of rectifier and antenna structures. The RFEH antennas have been designed for single, dual and multi band applications. A Rectenna for RFEH Harvesting was designed in [2]. The resonant frequency used for the design of rectenna is 2.45GHz. An antenna is proposed for dual frequency band applications in the ISM band and WiMAX band in [1]. To make the energy harvesting system operate for multiple bands, A Dual-Band Antenna for RF Energy Harvesting Systems in Wireless Sensor Networks [4], has been designed. The aim here is to increase the efficiency of energy harvesting for the 2.4GHz and 5GHz band. Integration of this antenna with RFEH system can be easily achieved on a single circuit-board. Evaluation of antenna performance and investigation of effects of different parameters on the antenna design was conducted by carrying out simulations and measurements. As demand for various communication bands started increasing, antennas capable of operating for multiple bands were required to be designed. To achieve this, an antenna with triple band for efficient RF energy harvesting was designed in [5]. The work presented by the authors is based on the design of an antenna radiating at three different frequencies to harvest RF energy from various cellular networks, wi-fi and WiMAX sources. A triple-band sensitive voltage doubler is also designed in this paper. The efficiency provided by the rectifier is in the range of 42, 46 and 80 percentage at 2.44GHz, 1.95GHz and 940MHz respectively. Another work on rectenna system with antenna operating for multiple frequencies was designed. A wideband rectenna for 2.4GHz band was designed for harvesting RF energy [7]. With such antenna designs, several RF energy harvesting systems with good conversion efficiency were proposed and implemented. [8] proposes a work on Antennas for Ambient RFEH in Wireless Body Area Networks, which made an effort in identifying spectrum circumstances for

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RFEH by power density measurements in the 350MHz to 3GHz range. In this work a Dual band inset fed rectangular microstrip patch antenna is designed for 2.35GHz and 3.7GHz having simple design geometry and improved Return loss, VSWR and Directivity required for RF energy harvesting system used in WSN applications is designed.

III. ANTENNA DESIGN

Design specification: Narrow band, Dual band microstrip patch antenna with inset feed working at 2.35 GHz and 3.7 GHz is designed. First, an antenna with a patch printed on substrate is designed for 2.4 GHz. The antenna uses a FR-4 Epoxy dielectric substrate of thickness h = 1.6 mm. It has a relative permittivity of ϵr = 4.4. Length of the patch L_p = 27.14 mm and Width Wp = 38.03 mm. The Width and Length of the Substrate are 70mm each. The dimensions for the antenna are calculated using the formulae given below:

1. Width of Patch $W_p = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$ = **38.03 mm**
2. Dielectric constant $\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{w}]^{\frac{-1}{2}}$ = **4.78**
3. Length extension $\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)[\frac{W}{h}+0.264]}{(\varepsilon_{reff}-0.258)[\frac{W}{h}-0.8]}$ = **0.72 mm**
4. Effective Length of Patch $L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$ = **28.58 mm**
5. Length of Patch $L_p = L_{eff} - 2\Delta L$ = **27.14 mm**
6. $Y = \frac{W}{5}$ = **7.606 mm**
7. $X = Z = \frac{2W}{5}$ = **15. 212 mm**
8. H(depth) = 0.822 * $\frac{L}{2}$ = **11.150 mm**
9. L1 (Length of Feed Line) = **35mm**
10. W1 (Width of Feed Line) = **3mm**
11. Width of the Substrate = **70 mm**
12. Length of the Substrate = **70 mm**
13. Inset gap g = (Y – W1) / 2 = **2.03 mm**

The Fig. 2 shows the structure of the patch antenna with inset feed. Using the above measured design parameters, a single band microstrip rectangular patch antenna is designed for 2.4GHz.

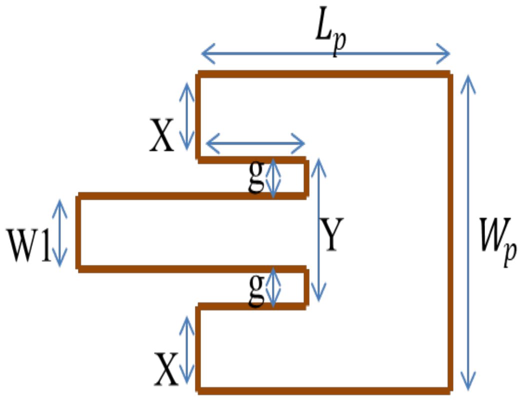

Fig. 2: Structure of Patch antenna with inset feed

To make the antenna resonate at the second frequency certain changes are made to the design parameters. Table 1 shows the optimized design values for the dual band antenna for Wi-Fi and WiMAX bands.

Table 1: Design parameters of Dual band antenna

Antenna Parameters	Dimensions in mm
Width of the Substrate	70
Length of the Substrate	70
Width of the Patch	38.0362
Length of the Patch	29.4431
Width of the Feed	1.5
Length of the Feed	30
Inset Distance	11.1504
Inset Gap	1.8

IV. SIMULATION RESULTS

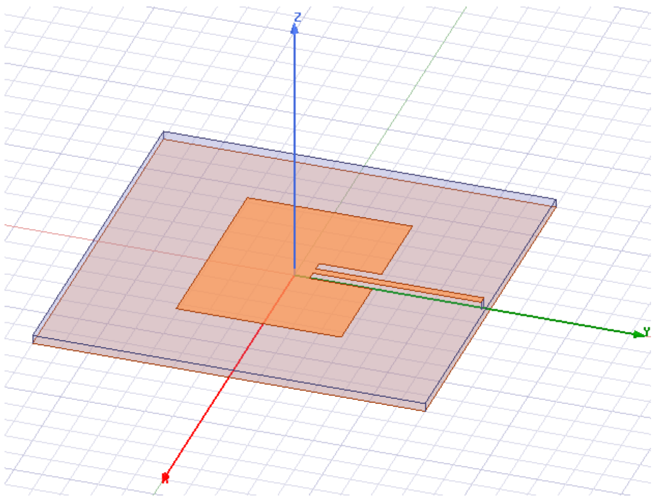

Fig. 3: Simulated Inset Fed Dual Band Antenna

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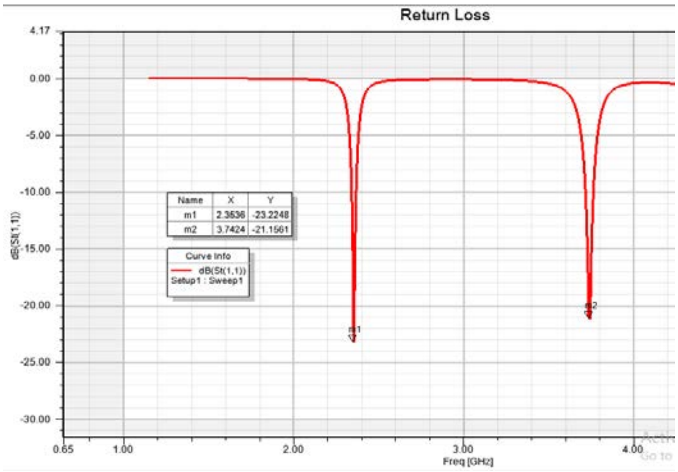

Fig. 4: Return Loss

Fig. 4 gives the Return loss for the antenna. We achieve a return loss of -23.23 dB and -21.1561 for 2.35 GHz and 3.7 GHz respectively

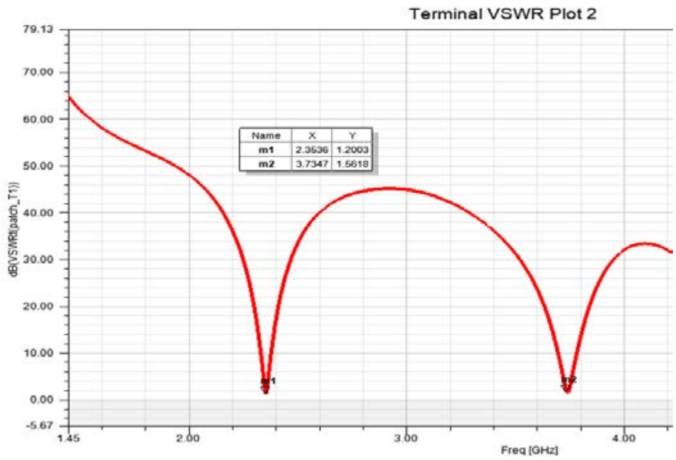

Fig. 5: VSWR

Fig. 5 shows the VSWR achieved for the antenna. We obtain a VSWR of 1.2 and 1.56 for 2.35 GHz and 3.7 GHz.

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Fig. 6: 2D Gain Plot

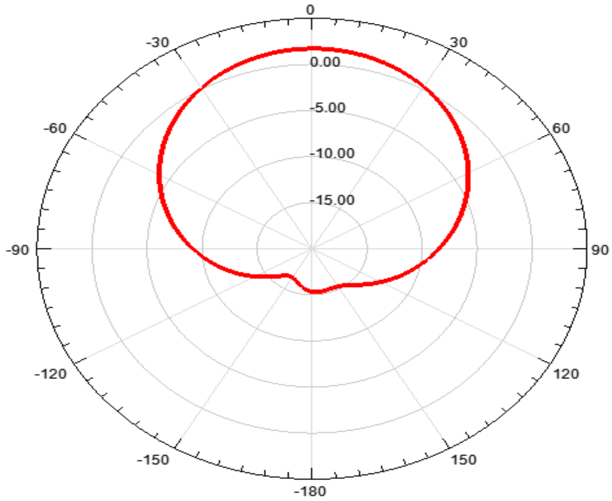

Fig. 7: 2D Radiation Pattern

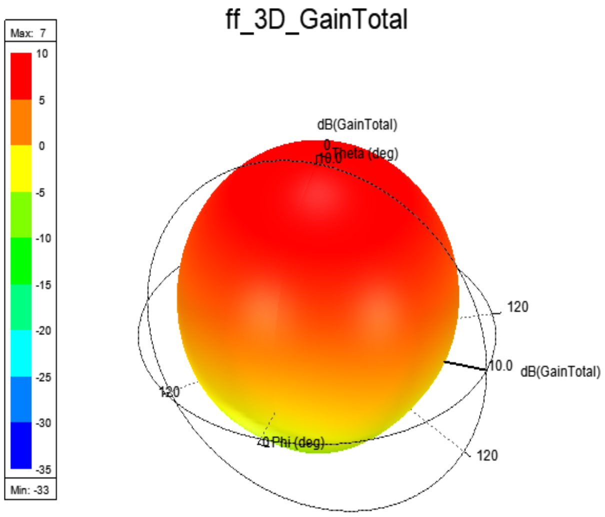

Fig. 8: 3D Radiation Pattern

Fig 6 gives the 2D gain plot of the antenna, Fig 6 and Fig 7 show the 2D and 3D Radiation pattern. From the results we can observe that there is a 6.5 dB gain and the 3D radiation pattern shows that the antenna is omnidirectional. The results are tabulated in the Table 2

Table 2: Simulated results of the Antenna

Parameters	Output
Return Loss (2.35 GHz)	-23.23 dB
Return Loss (3.7 GHz)	-21.16 dB
VSWR (2.35 GHz)	1.20
VSWR (3.7 GHz)	1.56

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V. Conclusion

In the paper given an patch antenna with inset feed method is designed for dual band frequency of 2.35GHz and 3.7GHz. The antenna proposed is a rectangular microstrip patch antenna having inset feed, the substrate used is FR-4 Epoxy. The antenna is simulated, tested and optimized using Ansoft HFSS software. The Antenna designed can be used for RFEH System when integrated with Rectifier to receive the radiations in WiFi and WiMAX frequency bands. Various parameters such as dimension, shape of the substrate, patch and feed that affect performance of the dual band antenna are shown in the Table.1. Corresponding results obtained are shown in Table 2. It can be observed that a return loss of -23.23dB and -21.16dB and a VSWR of 1.20 and 1.56 is obtained for 2.35 GHz and 3.7 GHz. The gain is found to be 6.5 dB. All these output parameters and simplicity in the design geometry make the designed Inset Fed Microstrip Patch antenna suitable for RFEH system used in WSN applications.

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