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A Wideband Microstrip Patch Antenna with Integrated Circular Slot for RF Energy Harvesting

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Abstract: ***This paper presents a wideband Microstrip patch antenna with integrated circular slot for radio frequency energy harvesting. The antenna consists of circular slot and stubs with a coaxial feed. The proposed antenna consists of four symmetric gap. It is designed on FR4 lossy epoxy substrate material for 2.65GHz frequency allocated for Wi-max application. Circular slot are integrated inside a square patch of proposed antenna which helps to increase the bandwidth of antenna.***

Keywords**: *Circular slots, RF energy harvesting (RFEH) system, Microstrip patch antenna.***

I. INTRODUCTION

RFEH is further connected more researchers as an alternate resolution to temporary battery life [1]. Energy harvest could be a promising technology which will like millions of radio transceiver all over the world [2]. Radio transceiver like cell phones, television, broadcast stations are radio frequency energy sources. Energy which is harvested from the environment can be reused [3]-[4]. The RFEH includes an antenna, a matching circuit and a rectifier. Diagram of RFEH system is shown in given figure 1. In harvesting system antenna is implemented at receiver end and it takes electromagnetic waves as its input, a rectifier circuit [5].

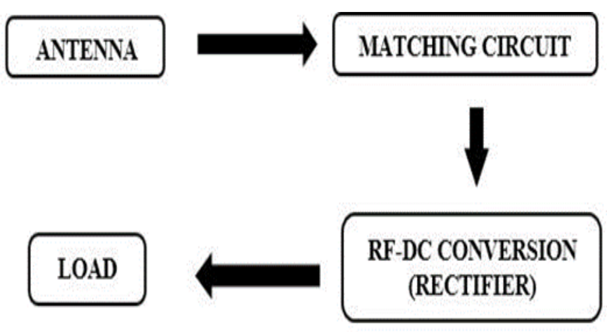

Fig. 1 Diagram of RFEH System

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Wi-max is application which is used at 2.65 GHz and it is a service of wireless broadband communication [6]. Wi-max is for the WAN(wide area network) and is much faster, WAN connects several LANS (local area network).The RF signal range from 3KHz to 300GHz be the source or medium to any radio frequency harvesting system. RFEH have found their applications in forms like wireless charging system, wireless sensor network etc [6]-[9]. RF energy harvest home technique relies on the extracting energy from close that is EM waves radiated from completely different sources of communication [3].

II. ANTENNA DESIGN

A Wideband Microstrip patch antenna with integrated circular slot is designed, the cross sectional view with coaxial feed technique of proposed circular slots antenna is shown in figure 2.Square microstrip patch is placed in the x-y plane. Size of microstrip patch is 24mm × 24mm. Co axial feed is placed along the negative y axis.

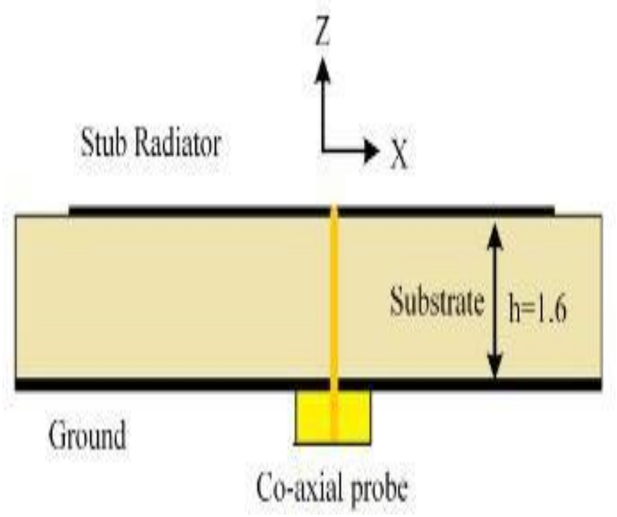

Fig. 2 Cross sectional view

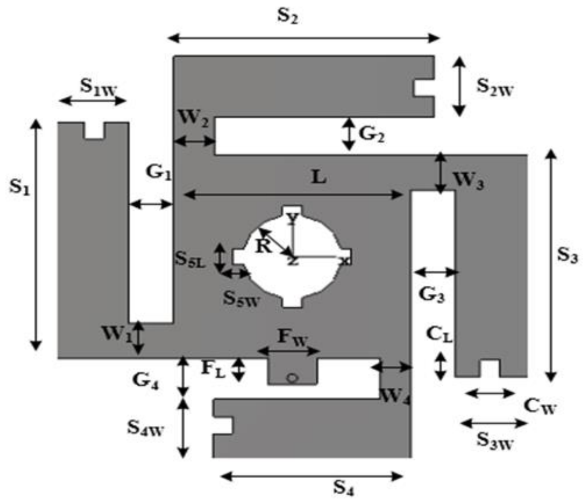

Fig. 3 Circular slots radiator

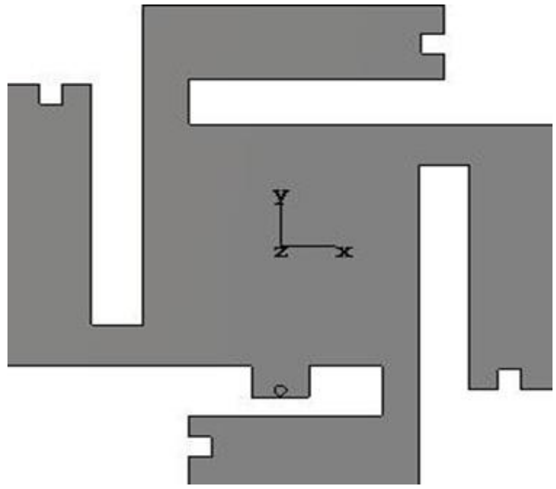

Fig. 4 Antenna without slots

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
S_1	28	C_W	2
S_2	26.3	C_L	2
S_3	26.3	L	12
S_4	20	R	5
S_{1W}	7.3	S_{5L}	2
S_{2W}	7.3	S_{5W}	4
S_{3W}	7.3	W_1	4.1
S_{4W}	6.9	W_2	4.1
G_1	4.9	W_3	4.1
G_2	4.9	W_4	3.1
G_3	4.9	F_L	3.1
G_4	4.9	F_W	5

Table 1 - Circular slot antenna design dimensions

Four symmetric length stubs are introduced and integrated with square patch with symmetric gaps is shown in figure 3. The length of stubs $S_1 \neq S_2 = S_3 \neq S_4$. Along the negative y-axis of square patch a feeding stub is integrated with width Fw and length F_L. Parameter inside the square patch of circular slots are S_{5L}, S_{5W}, R. All designing dimensions parameter of antenna is shown in table 1.

III. RESULTS & DISCUSSION

Figure 4 shows the antenna without circular slots and figure 3 shows the antenna with circular slots, without using slots the antenna is not able to achieve the proper results as its return loss is less than -10dB and it does not have the bandwidth, whereas the presence of slots gives better bandwidth of 200MHz and return loss is also more than -10dB with the frequency band of 2.65GHz, which shows that the antenna is equal in shape and size but with slots it gives proper results.

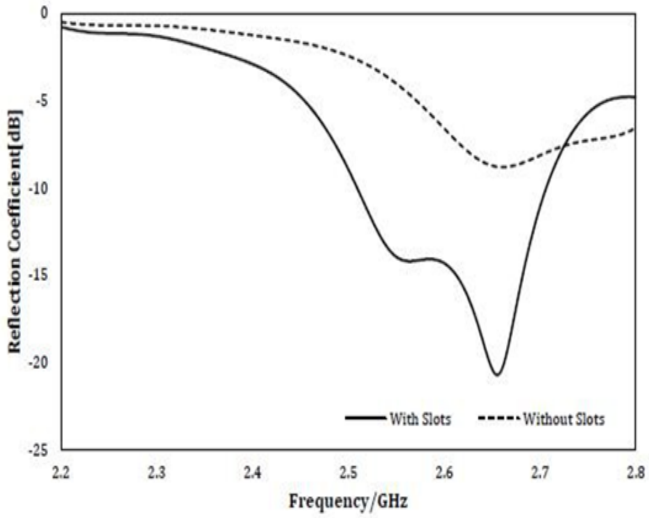

Fig. 5 Compare graph of both the antenna

The simulated S_{11} (Reflection coefficients) of both the proposed antenna (without slots and with slots) is shown in figure 5 which shows that antenna is more efficient with slots, the antenna covers 2.65GHz frequency band which is useful for RFEH prospective. The designed antenna is manufactured and experimentally tested to verify the simulations result, the picture of fabricated antenna is given in figure 6. It is printed on a low cost commercially of obtainable FR- 4 lossy substrate ($\varepsilon_r = 4.3$, tan $\delta = 0.025$, h= 1.6mm).

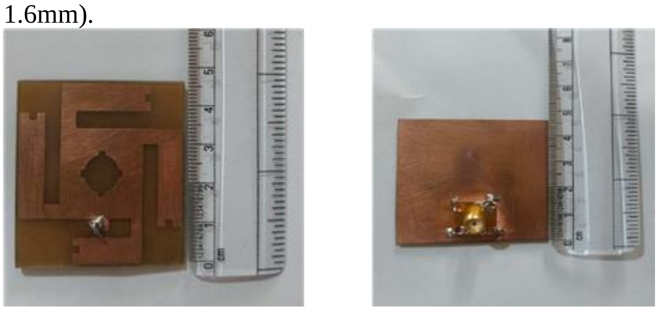

Fig. 6(a) Front view of fabricated (b) Back view of fabricated antenna

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Figure 7 shows simulated radiation pattern of antenna in the x-z planes and y- z planes (phi= 0˚and phi= 90˚) at resonating band of antenna. At phi =0˚the radiation pattern is unidirectional and at phi=90˚the radiation pattern is also unidirectional with some distortion, the radiation pattern may distorted sometimes due to adaptors or connectors which is used in the measurement it may pick up the spurious radiation from unwanted direction. Figure 8 shows simulated gain of antenna, the simulated gain is suitable for RF signal harvesting. Figure 9 shows the simulated and measured result of proposed antenna, the performance of wideband microstrip patch antenna was measured on FS315 spectrum analyzer, it is clearly observed that there is small discontinuity between simulated and measured result, this is because of cable losses and environmental effects.

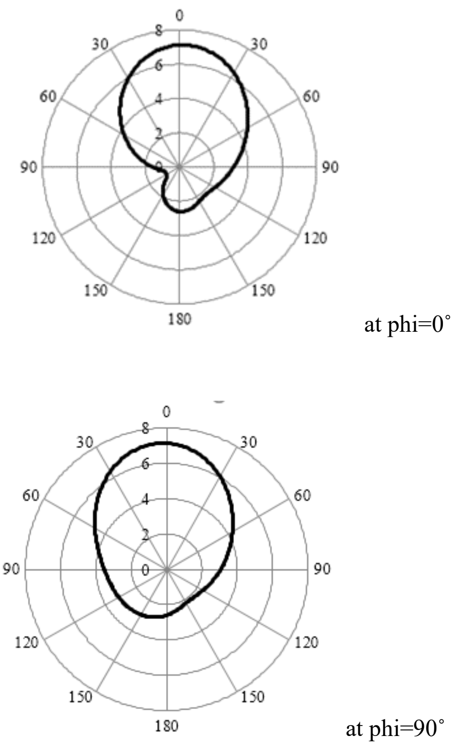

Fig. 7 E-field pattern

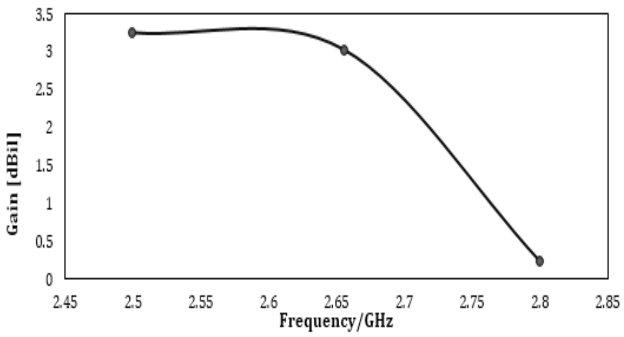

Fig. 8 Gain of proposed antenna

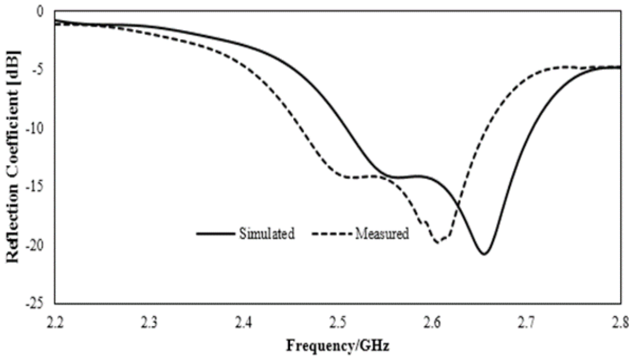

Fig. 9 Reflection coefficients of simulated and measured result of proposed antenna

III. RECTIFIER DESIGNING OF ANTENNA

RF energy system receives signal from RF transmission and receiving sources. It contain antenna that receives or transmits the radiated power from the close RF sources [15]. The rectifier will receive EM signals and converted it for the conversion of RF energy into dc energy. The RF dc conversion strength depends on i/o power of rectifier. Maximum the input power more is the dc conversion strength of rectifier [10-14]. For converting RF power into DC power full wave bridge rectifier is used. Voltage doubler is used for increment of DC power input signals [13]. Diode 1N4148 is a silicon diode which is operated at high frequency and having fast switching response. Circuit diagram of FWBR (full wave bridge rectifier) is shown in figure 10. Parameters used in bridge rectifier is diodes, capacitor and load as LED.

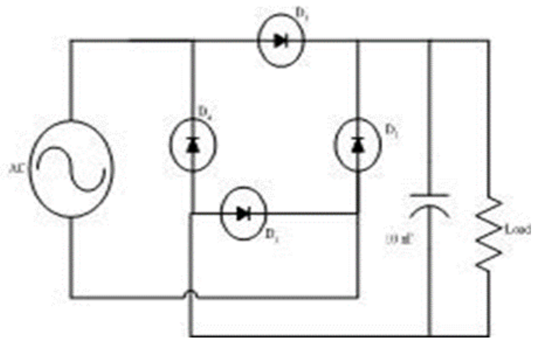

Fig. 10 Diagram of FWBR

Electromagnetic waves is transmitted by antenna which is taken as an input for FWBR circuit. Diode D1 is forward bias and D2 is also forward bias in positive half cycle, the diode D1 is forward bias from the positive half cycle and diode D2 is from the negative half cycle and vice versa[12]. Simulated result of bridge rectifier confirms that element chosen within rectifier are capable of operating within the input frequency vary. RF to DC conversion depends on the i/o power at the rectifier terminal. Since, the conversion efficiency can be determined from equation:

$$\eta = P_{DC} / P_{RF} \times 100 \qquad (1)$$

The maximum converted RF to DC power of proposed work is 42% as shown in figure below.

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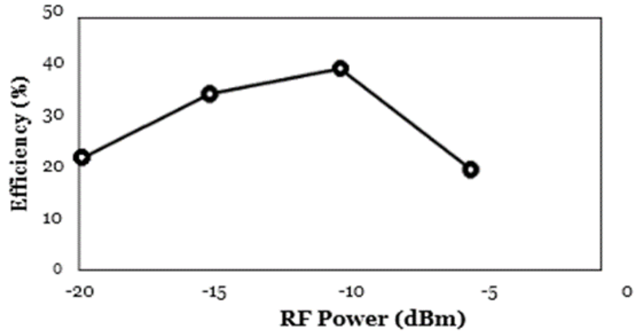

Fig. 11 RF-DC Conversion

The voltage measured across the load of the rectifier by glowing the LED is shown in figure 12. Cellular GSM mobile phone radiates the RF signal. Mobile phone is kept near the rectifier circuit. The voltage measure across the load is 0.560mv. The load voltage is measured by voltmeter across the terminal.

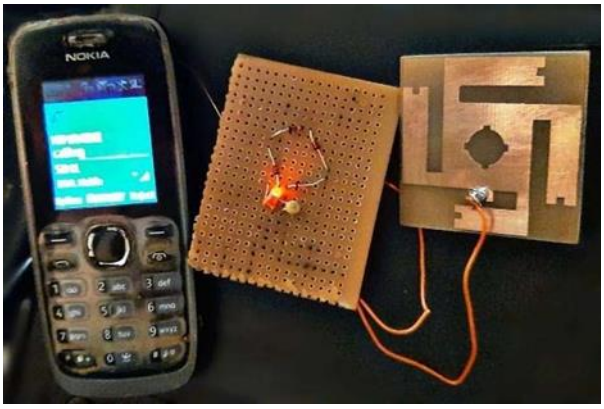

Fig. 12 RF energy harvesting by glowing LED

V. CONCLUSION

A Wideband Microstrip patch antenna with integrated circular slot is designed on FR-4 substrate for RFEH and bandwidth enhancement applications. The band 2.65 GHz response of the antenna covers the frequency range of same, design includes circular slots for reducing the size of the patch antenna and increasing the bandwidth. The small size of antenna and radiation pattern helps in energy harvesting applications. For further research in this proposed work, bandwidth enhancement for same structure is required.

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