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Research paper

Low profile microstrip fed printed antenna for portable RF energy harvesting system

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Abstract

This work presents, a printed wideband microstrip antenna that can be used for portable RF energy harvesting applications. The antenna is designed, simulated and validated using 3D electromagnetic HFSS simulator. The targeted frequency band of operations are from 0.825 GHz to 1.05 GHz for catering GSM/3G wireless applications. Following the antenna design in the HFSS software, the structure has been fabricated on low cost substrate FR4 and the structure performance is analyzed experimentally. The achieved wideband, omni directional patterns with constant gain monopole antenna can be suitable for all portable system applications.

Keywords: *Microstrip Antenna; Printed Antenna; RF Energy Harvesting; Small Antenna; Wideband Antenna*.

1. Introduction

As the utilization of power is increasing, the need for alternative energy sources has become more demand. Many different energy sources such as light, wind, temperature has been transformed into usable energy using distinct number of techniques. This has recently attracted a method of harvesting ambient radio energy for promising an alternative to existing energy sources. Increased use of mobile phones, Wi-Fi and cell tower installations produces abundant radio frequency (RF) energy ambient or areas close to the transmission towers. Thus to harvest RF energy from these sources, RF signal receiving antenna is required. Furthermore, the receiving antenna is to be connected to the RF to DC rectifiers for power conversion. The converted DC power can be used to recharge the batteries of wireless devices or to power up small electronic devices such as USB connected LEDs, fans. The overall system of energy harvesting consists of a receiving antenna and a harvesting circuit. In view of this, various types of antennas have been designed in many papers [1-28].

A textile monopole antenna with multiband was designed in [1], covering DTV band, GSM-900, advanced UTMS-LTE, WLAN (2.4GHz/5.8 GHz) and WiMAX (3.5GHz). Chip inductor has been embedded in the antenna to attain lowest resonant mode excitation [2]. An inverted-L shape conducting strip was soldered at the one edge of the composed antenna to extend the electrical length for GSM band operation [3]. A printed monopole antenna operated with in dual band parasitic element shorted strips has been proposed to operate at LTE/ WWAN bands [4]. A twisted line inverted-F shape antenna with wide band operating characteristics has been designed for dual band applications [5]. Slots and slits were employed in the antenna to obtain multiband characteristics [6].

A wide band planar antenna for mobile handset applications has been implemented [7]. A monopole three slot antenna has been proposed For laptop computers for wireless wide area network operation [8]. A Radiating patch having octagonal shaped slot antenna fed by rectangular stepped shape patch has been presented to cover GSM and UWB bands [9]. A multi band antenna was presented in [10], the radiator shape was in dome like shape and it is operated in the Ultra wideband range. A rupee symbol shape printed multiband antenna presented in [11], it is operated at the three bands and metal strips were used as additional resonators for multiband operation. Two strip monopole configuration of an antenna resulted in wide band at low frequency [12]. Dual crossed C-slot patch radiators were present in the antenna for triple band operation [13]. The presented antenna consisting of two loops, an inner inverted L strip connected covered an outer loop strip was created for GSM and Digital communication applications [14]. In [15] compact triangular shaped monopole geometry was reported for UWB applications.

From the literature it is observed that most of the reported printed antennas were focused on design of wideband and that to on UWB frequencies and very few were developed for GSM applications. So it is observed that, to cater the GSM and 3G frequency applications a wideband with simple geometry and small in size single/multiband antenna is needed. In this paper, we have presented a PCB (Printed Circuit Board) antenna which is relatively cheap and easy to print on substrates. The proposed antenna is a wide band antenna which works at a frequency range of 0.82 to 1.05 GHz.

2. Antenna design

An asymmetrical microstrip antenna shown in the Fig 1 is printed on glass epoxy FR4 substrate with dielectric constant of 4.4, loss tangent of 0.02 and thickness of 0.8 mm. It illustrates that, the radiating patch element and feed line are printed on the one side of the substrate and the ground plane with a rectangular shaped notch printed on another side of substrate. The feed line width is chosen

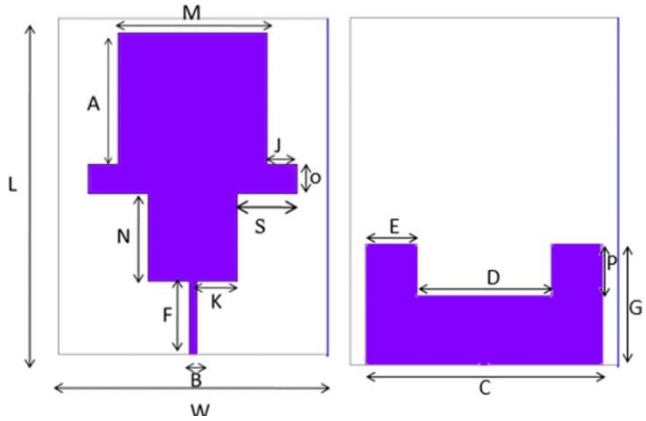


Fig. 1: Low Cost Printed Antenna Configuration.

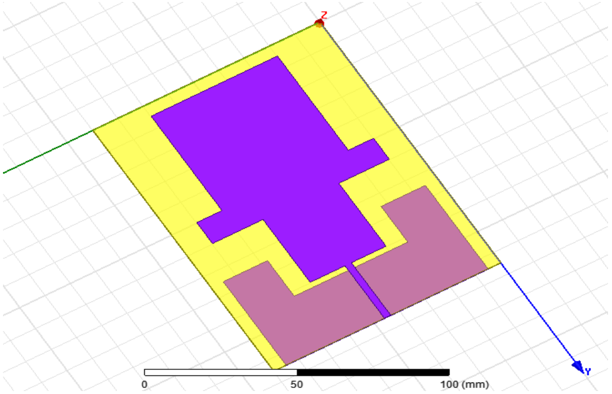


Fig. 2: 3-D View In HFSS Software.

As 2 mm for the characteristic impedance of 50Ω. The detailed dimensions of the designed antenna after optimization of dimensions are (L=115, W=90, A=45, M=50, F=25, O=10, B=2.5, K=13.75, J=10, N=30, E=17.5, S=20, G=40, C=80, P=17). Designed antenna with detailed dimensions in 3 Dimensional view is illustrated in the Fig 2 and 3.

The radiating patch printed on the top of the substrate and modified rectangular ground plane is printed on the bottom layer of the substrate. The proposed wide band performance has been achieved by three evolution stages shown in Fig 4. It demonstrates that in first stage (Antenna 1), a simple rectangular radiating patch with rectangular ground plane is shown in Fig 4(a). In Antenna 2, two rectangular strips etched from the Antenna 1 and with same rectan- gular ground plane is shown in Fig 4(b). By adding extra rectangular plane strips to the radiating patch of Antenna 2 and ground plane of the Antenna 2, extracted Antenna 3 is shown in Fig 4(c).

3. Results and discussion of proposed antenna

The simulated and measured return loss (S11) plot, VSWR(Voltage Standing Wave Ratio), evolution stages, current distribution and the 2D and 3D radiation pattern results of the designed an- tenna(simulated and measured) are shown in the following sections.

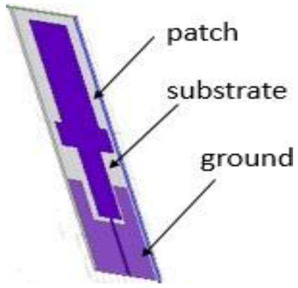


Fig. 3: 3D View in HFSS Software.

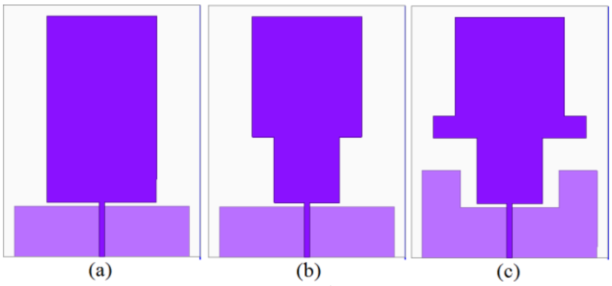

(a) (b) (c)

Fig. 4: Evolution Stages of Composed Antenna.

3.1. Return loss

The simulated reflection coefficient comparison among the all antennas i.e. Stage #1 (Fig: 4(a)), Stage #2 (Fig: 4(b)) and Proposed antenna (Fig: 4(c)) is shown in Fig 5. It illustrates that, the impedance bandwidth of the Stage #1 is above -10 dB at 0.99 GHz resonant frequency. The modified patch named as Stage #2 is having the impedance bandwidth ≤of 10 MHz in the centre frequency of 0.9 GHz. To achieve wide band characteristics, radiating patch element and ground plane has modified as result impedance bandwidth of 225 MHz, range from 0.825 GHz to 1.05 GHz has achieved for S11 10 dB is shown in Fig 6. It is observed from the plot that, by adding the numbers of radiating strips are pro- portional to the operated spectrum frequency bands of the composed antenna and by inserting radiating elements, the operating frequency range shifts towards lower frequencies.

The proposed antenna's return loss plot is measured in Anritsu Net- work analyzer, shown in the Fig 7. It shows that resonant mode frequency of 0.89 GHz frequency and its operating frequency range is nearly 0.81 GHz to 1.2 GHz.

3.2. VSWR

Simulated Voltage standing wave ratio (VSWR) plot of proposed antenna is shown in Fig 8. It illustrates that satisfies within the

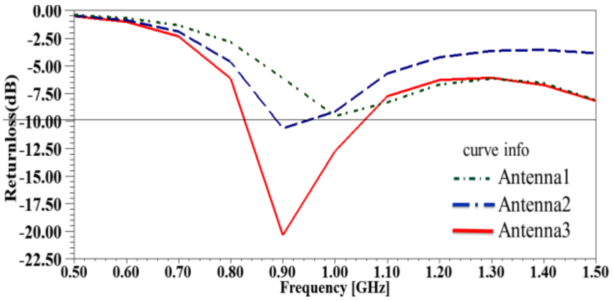


Fig. 5: Modified Rectangular Antenna S_{11} Curves.

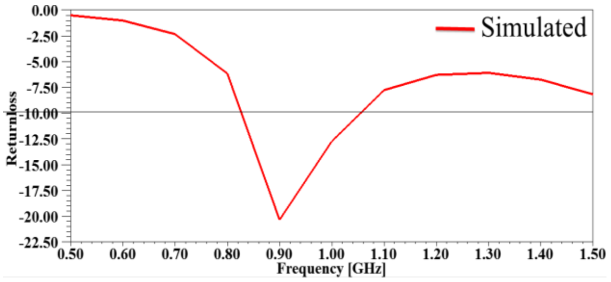
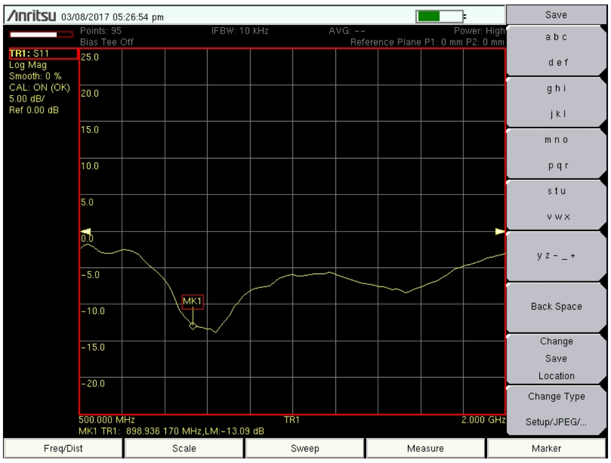


Fig. 6: S_{11} versus Frequency Simulated Plot.



Points: 95 IFBW: 10 kHz AVG: -- Power: High
Bias Tee Off Reference Plane P1: 0 mm P2: 0 mm
TR1: S11
Log Mag
Smooth: 0 %
CAL: ON (OK)
5.00 dB/
Ref 0.00 dB
500.000 MHz 2.000 GHz
MK1 TR1: 898.936 170 MHz,LM:-13.09 dB

Fig. 7: Tested Return Loss of Antenna Prototype.

Operating frequency range below 2 at 0.9 GHz frequency. The mea- sured VSWR plot shown in Fig 9, at 0.89 GHz resonant frequency. Simulated and measured plots nearly equal each other.

3.3. Surface current distribution

The simulated surface current distributions at selected frequencies of the proposed antenna have been computed over distinct frequency of operation and shown in Fig 10. The multiple radiating branches of the designed antenna exhibits wide operating bands as they represent distinct lengths of current. At 0.8 GHz frequency large current flows along the feedline and top edges of ground plane is depicted in Fig 10(a). At 0.9 GHz frequency large current flows along the feedline and top edges of ground plane is depicted in Fig 10(b). At 1.0 GHz frequency large current flows along the feedline and less current flow observed at top edges of ground plane, it is shown in Fig 10(c).

As frequency increases the density of current on a radiating patch slightly decreasing, indicates that it cannot operate at the more than these frequencies. Therefore current distribution is low over the higher frequencies.

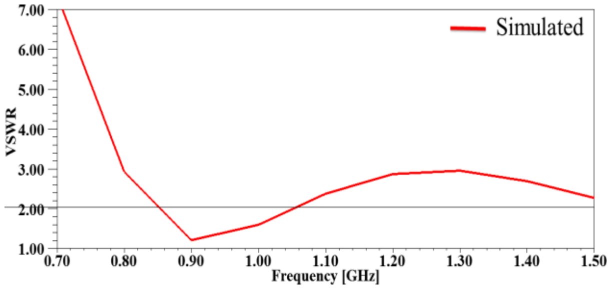
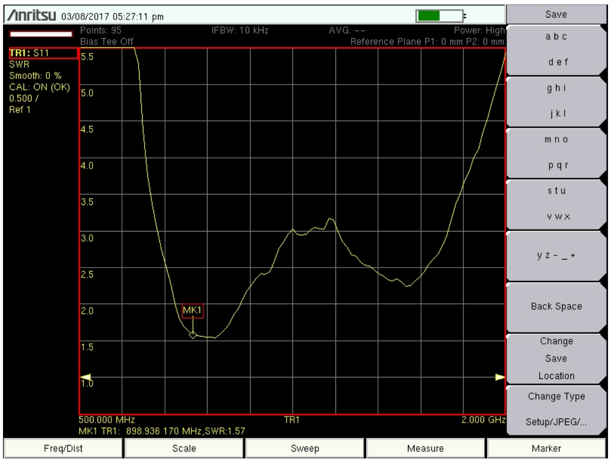


Fig. 8: Simulated VSWR versus Frequency Plot.



Points: 95 IFBW: 10 kHz AVG: -- Power: High
Bias Tee Off Reference Plane P1: 0 mm P2: 0 mm
TR1: S11
SWR
Smooth: 0 %
CAL: ON (OK)
0.500 /
Ref 1
500.000 MHz 2.000 GHz
MK1 TR1: 898.936 170 MHz,SWR:1.57

Fig. 9: Measured VSWR Plot of A Printed Antenna.

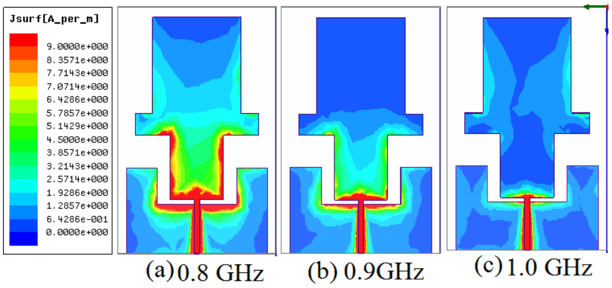


Fig 10: Current Distribution of Designed Antenna at Distinct Frequencies.

3.4. Radiation patterns

The simulated 2D and 3D radiation patterns of the proposed and designed antenna in the both E and H-plane at selected frequencies were measured and tested in an anechoic chamber and shown in Fig 11, 12 and 13 respectively. It illustrates that almost omni directional radiation pattern in the H-plane and figure of eight pattern in the E-plane over the all frequencies.

At 0.8 GHz, 0.9 GHz and 1.0 GHz frequencies, radiation pattern along the E-plane shows omni directional and along the H-plane the pattern is equaled as figure of eight shape. In Fig 12 shows, 3D radiation pattern of proposed antenna at 0.8 GHz, 0.9 GHz and 1.0 GHz frequencies respectively. High radiation occurs uniformly at all three frequencies.

The layout of the proposed and fabricated antenna is shown in Fig 14. It comprises of three asymmetrical rectangular shaped radiating strips placed in irregular manner, shown in Fig 14(a) and on the other side a simple rectangular ground plane with rectangular slot cut was introduced, shown in Fig 14(b). The overall geometry has been printed on both sides of 115 x 90 mm^2 size FR4 substrate. Its fabricated photograph shown in Fig 14.

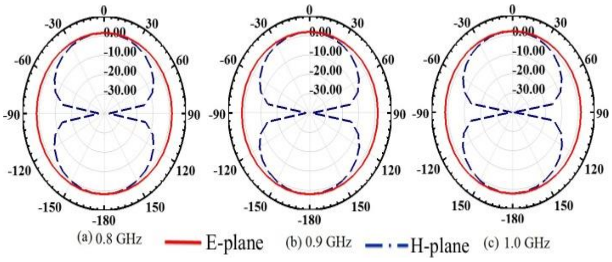


Fig. 11: 2-Dimensional Simulated Radiation Patterns of Antenna at (A) 0.8 Ghz, (B) 0.9 Ghz and (C) 1.0 Ghz Frequency.

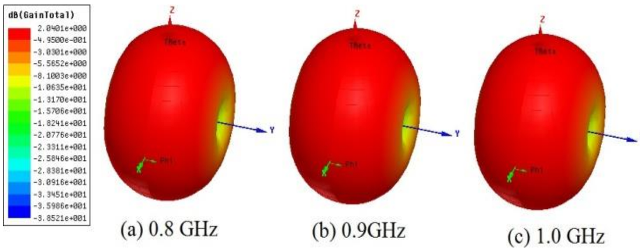


Fig. 12: 3-Dimensional Radiation Pattern of Antenna at (A) 0.8 (B) 0.9(C) 1 GHZ Frequency.

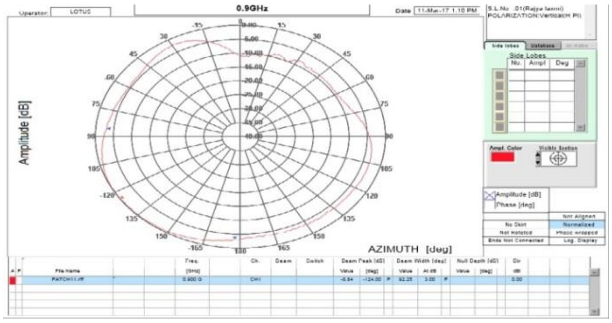


Fig. 13: Tested Radiation Pattern of the Antenna at 0.9 GHZ.

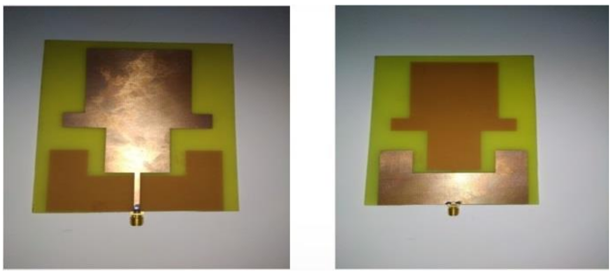


Fig. 14: Fabricated Antenna Top View and Bottom View.

4. Conclusion

A PCB based printed antenna is designed for the RF energy harvest- ing applications, using HFSS software. The maximum simulated return loss of the developed structure is -20dB at 900 MHz frequency and VSWR is less than 2 at a frequency range of (0.82-1.05) GHz. The designed antenna simulated results such as radiation pattern, current distribution, VSWR and return loss are done through ANSYS HFSS software and discussed. The designed antenna radiation pattern shows good Omni-directional performance throughout the specified and operated frequency range. The simulated results of proposed antenna are comparable with the experimental results of the fabricated antenna.

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