Design of Hybrid Fractal Boundary Antenna for RF Energy Harvesting Applications

Amritpal Kaur, Balwinder S. Dhaliwal, Suman Pattnaik

Abstract- The fractal antennas have multiband behavior and also have the capabilities of the size reduction as compared to the other patch antennas. Ahybrid fractal boundary antenna has been designed and simulated in this paper for radio frequency energy harvesting (RFEH). The designed antenna has the multiband behavior, as it resonates at the two frequencies. The multiband behavior of the antenna helps in harvesting the energy from various frequencies band and improves the output of the circuit. This hybrid fractal boundary antenna uses the microstrip feed line to improve the matching performance of the antenna.
Index Terms: Fractal antenna, Hybrid fractal boundary antenna, Radio Frequency (RF), Energy Harvesting (EH).

I. INTRODUCTION

The emergent need of wireless devices requires power wirelessly hence motivating research towards the energy harvesting and it is the requirement of now days. The RF energy harvesting (RFEH) is a way out toward this. RFEH gather the radio frequency (RF) energy existing in the environment and transform it into the required electrical energy [1]. RFEH technique has the ability to produce low amount of power mostly required for large number of devices now days. RF energy is abundantly present in the environment from the mobile communication systems, radio broadcasting, wireless local area network (WLAN) and in many other forms of systems that uses the RF signals for communication.The RFEH system needs a harvesting system to scavenge the RF energy from the environment. The RFEH system includes the antenna, matching circuit, rectifier and energy storage device to store the energy. This system is also referred to as rectenna [2].

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The RF energy sources divided in two parts ambient and the dedicated energy sources. Ambient sources harvests the energy from the RF energy present in the environment and are not dedicated but the dedicated rectennas harvests energy only from their dedicated source [3]. In paper [4]authorsdescribed,the various sources of RFEH shown with their frequency band and the amount of power that can harvested from them.The main part of the RFEH system is antenna, which captures the RF energy and converts it into the usable form. In paper[5] antenna designed for RFEH operates in the 2.45 GHz band with high efficiency.

Fractal antenna gainedboundary antenna analyzed in [8] is a triple band circularly polarized antenna and suited for wireless applications. In [9] the UWB antenna designed with the fractal popularity due its multiband feature and size reduction capabilities. The fractal antennas designed for RFEH in [6], [7] gives the multiband frequency operation. The Koch fractal boundary exhibited the omnidirectional patterns over wide range with the compact size of antenna. A hybrid fractal boundary antenna has been designed in [10] with Koch and Minkowski curve combination on the patch boundary. This antenna resonates in triple bands with high radiation efficiency.
In this paper, a hybrid fractal boundary antenna is proposed for RFEH. The Section I in paper presents the introduction and Section II describes the proposed antenna design Section III is about the results and discussions and the last Section IV is concludes the paper.

II. PROPOSED ANTENNA DESIGN

The starting shape of the antenna is square patch and then the circular slot is cut with the radius equal to half of the length of basic square and the crown square patch added to the geometry forms a crown fractal antenna. This geometry is proposed and analyzed in [6]. The authors in [6] have shown that as the antenna iterations increases the antenna behaves as multiband and the frequency separation decreases. The crown square fractal antenna in [6]has been modified and proposed as the hybrid fractal boundary antenna. The Fig. 1(a) shows the crown square fractal antenna after adding the Minkowski curve at the boundaries of this antenna shown in Fig. 1(b) and Fig.

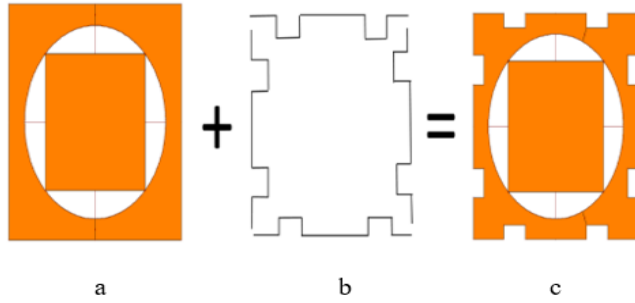1(c) shows the proposed hybrid fractal boundary antenna.

Fig. 1 (a) Crown square fractal antenna, (b) Minkowski curve, (c) Hybrid fractal boundary antenna

The antenna patch designed with thickness of 4 mm and dielectric constant used is 3.5. The outer or base square of the hybrid fractal antenna dimension 46.5 mm × 46.5 mm and radius of the circle is 19 mm with the inner square of 26.9 mm × 26.9 mm has the slot of crown square fractal antenna. The Minkowski curve added to the boundary of the antennahas the length and depth of 6 mm and 2 mm respectively and forming a hybrid fractal boundary antenna.
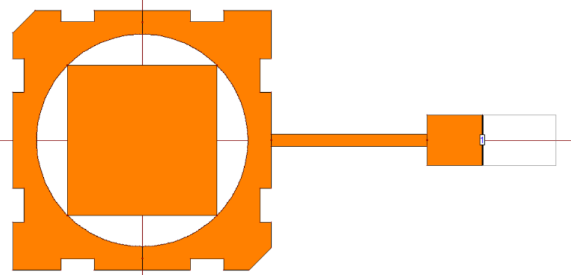

Fig. 2 Hybrid Fractal Boundary Antenna with Microstrip Feedline

This antenna geometry has been tapered at the opposite sideswith dimensions of 4 mm × 4 mm.Fig. 2 shows the modified hybrid fractal boundary antenna with the Minkowski curve and tapering on the opposite sides to enhance the results with the microstrip feed line. This fractal antenna employed the microstrip feed line to improve the matching properties. Themicrostrip feed line is of two sections and the dimensions are L1 = 28 mm and W1 = 2.2 mm the second section is of L2 = 10 mm and W2 = 9 mm as in [6]. Table 1 shows the dimensions for this hybrid fractal boundary antenna.

Table 1 Hybrid fractal boundary antenna dimensions

Parameter	Value
Length	46.5 mm
Width	46.5 mm
Circle Radius	19 mm
Feed Length	28 mm

Feed Width	10 mm
Feed Length	2.2 mm
Feed Width	9 mm

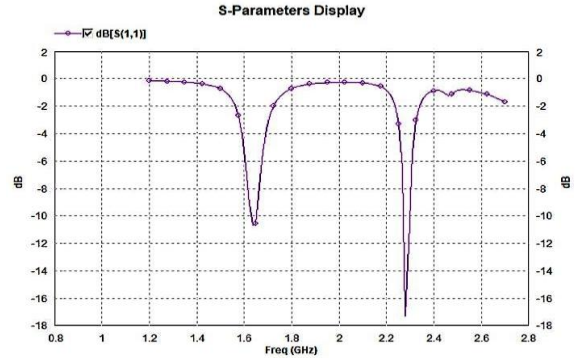Fig. 3 S$_{11}$ plot of the fractal antenna

III. RESULTS AND DISCUSSION

The simulation results of the designed antenna have been discussed in this section. The antenna designed and simulated in the IE3D software,which is a high performance EM wave simulator.Fig. 3 shows the S$_{11}$ plot of the fractal antenna with two resonant frequencies. The first resonant frequency is 1.63 GHz with the return loss of -10.67 dB and the second resonant frequency is 2.27 GHz with return loss of -17.08 dB. The proposed antenna has dual band behavior and its fundamental frequency has better matching than that of the reference antenna of [6]. So the proposed antenna has improved results as compared to earlier existing design. The bandwidth at the first resonating frequency of 1.63 GHz is 20 MHz and at the second resonating frequency, of 2.27 GHz is 30 MHz.

The crown square fractal antenna in [6] resonates at frequencies 1.575 GHZ and 2.6 GHz with the return loss of -9.3 dB and -16.8 dB respectively so the reference antenna do not have significant bandwidth at fundamental frequency.

So we got the antenna resonating at both the frequencies, with improved impedance matching as seen in terms of the return loss and also it has decreased the frequency separation. This antenna helps in harvesting the RF energy at two resonant frequencies.

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IV.   CONCLUSION

The hybrid fractal boundary antenna proposed for RFEH, resonates at the two frequencies, which are 1.63 GHz and 2.27 GHz with the return loss of -10.67 dB and -17.08 dB respectively. The antenna has bandwidth of 20 MHz and 30 MHz at the first and second resonating frequency. The proposed hybrid fractal boundary antenna shows the improvement in the results from the previous reference antenna in the case of its return loss and frequency separation. The further possibility of improvements in results is there to make the antenna more efficient.The hybrid fractal boundary antenna has great potential for RF energy harvesting due to its advantages of multiband and simple design.

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