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Compact Spiral Shaped Multiband Frequency Reconfigurable Microstrip Patch antenna for Wireless Applications

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Abstract

A novel, frequency reconfigurable rectangular spiral-shaped patch antenna for UHF, L, S and C band wireless applications is presented. The projected reconfigurable antenna is able to operate at nine frequency bands 0.878-0.895, 1.33-1.37, 1.75-1.84, 2.14-2.29, 2.665-2.85, 2.71-2.85, 3.43-3.77, 4.71-5.16, 4.76-5.22 GHz. Rogers RT5880 substrate material with $\varepsilon_r = 2.2$ *and thickness h =1.6 is used between radiating element and ground. By adding different strips, the radiating element changed into a rectangular spiral shape. Frequency reconfigurable is accomplished by integrating a PIN diode into a spiral arm. The proposed antenna displays VSWR of less than two, low return loss with appreciable gain, directivity and efficiency over desired frequency bands.*

Keywords: *Frequency reconfigurable antenna, PIN diode, Multiband antenna, Microstrip patch spiral antenna*

1. Introduction

The microstrip antenna has a significant role in this modern networking system for satellite, radar, aircraft, missiles, telephone and cellular communication systems [5]. Dielectric substrate material is placed between ground and patch. The dominant features of the microstrip antenna are compact, simple in shape, light weight, low volume, less cost and simple to incorporate with MIC [2].

An antenna that operates over several frequency bands gained significant attention because of the prevalence of new wireless technology and a demand from customers. Frequency agile antennas have capability to operate over multiple frequency bands without any added complexity and increase in the physical size of the antenna. In this perspective, an ordinary antenna can be converted into a reconfigurable multiband antenna that can be used for multipurpose with enhanced characteristics. Reconfiguration is accomplished in the microstrip antenna by radio frequency switches like varactor Diodes, PIN Diodes, and MEMS. PIN diodes are most used among these switches due to their dominant features like low cost, easy biasing, and very good reliability to achieve the reconfiguration frequency by adjusting effective antenna length.

Frequency reconfigurable compact slot antenna is introduced in paper [4], where, slots of L and U shaped are formed on the ground surface, to realise dual frequency bands. Fours switchable states, two single and two dual bands are achieved by using three PIN diodes within the slots. Frequency-Reconfigurable Microstrip Patch-Slot Antenna presented in [3], reconfiguration up to nine frequency bands is achieved but with five of PIN diodes. Flexible spiral-shaped reconfigurable antenna is presented in paper [1]. Multiple (five different frequency bands) resonances are achieved through spiral shape and PIN diode, but the gain of the antenna is low.

A compact, spiral shaped frequency reconfigurable multiband antenna with dimension of $50 \times 50 \times 1.6$ mm^3 is projected in this paper. The key benefit of the antenna is its ability to resonate at nine different frequency bands. Frequency agility is accomplished by a PIN diode (BAP50-02),

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positioned in the spiral arm. Nine different frequency bands ranging from 0.3 to 6 GHz are obtained. Section 2 covers the detailed configuration of the projected antenna. In Section 3, performance of the antenna with the results are presented and conclusion is done in Section 4.

2. Proposed Antenna design and configuration

2.1 Antenna geometry

On the substrate material Rogers RT5880 with ε_r of 2.2 and height h of 1.6 mm the antenna is designed. Computer Simulation Tool is used to perform simulations of projected antenna. Antenna structure is as depicted in figure 1 and dimensions are given in table 1. The patch is modified into rectangular spiral shape and partial ground plane as show in figure1. The spiral arms are separated by distance of 1 mm.

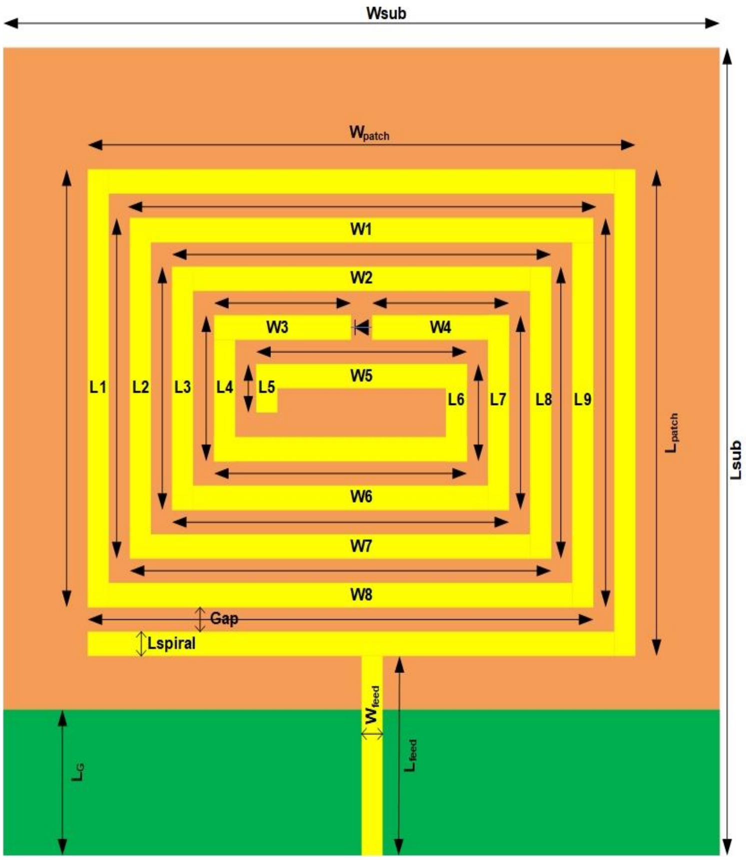

Figure 1: Geometry of the antenna proposed

Table1: Proposed design parameters (units are in mm)

Parameters	Dimension	Parameters	Dimension	Parameters	Dimension
Wsub	50	L1	18	W1	20
Lsub	50	L2	14	W2	16
Wpatch	24	L3	10	W3	5.5
Lpatch	20	L4	6	W4	5.5
Wfeed	3.2	L5	2	W5	10
Lfeed	15	L6	4	W6	14
Gap	1	L7	8	W7	18
Lspiral	1	L8	12		
L_G	11.12	L9	16		

50 × 50 x1.6 mm^3 is the volume of the proposed antenna. Spiral-shaped radiator is designed and it can resonate at nine different frequency bands. In one of the spiral arms (fourth from the top) a PIN diode is inserted to achieve the frequency agility. The proposed antenna is frequency

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reconfigured at seven frequency bands covering from 0.88 GHz to 5.03 GHz for diode ON condition and for OFF condition it is resonating at three different frequencies covering from 2.78 GHz to 5.06 GHz. One resonating frequency from ON and OFF conditions is overlapping so the proposed antenna is resonating at a total of nine different frequencies.

III. RESULTS AND DISCUSSIONS

The projected antenna performance is studied by considering VSWR, reflection coefficient, Gain and radiation patterns. Distributions of surface currents were also observed.

Case-I: For the diode forward biased condition the antenna resonates at seven different frequencies which covers UHF, L, S and C band applications. The return loss graph for forward bias condition is shown in figure 2. The evaluated parameters for the projected antenna when PIN diode is ON is presented in table 2.

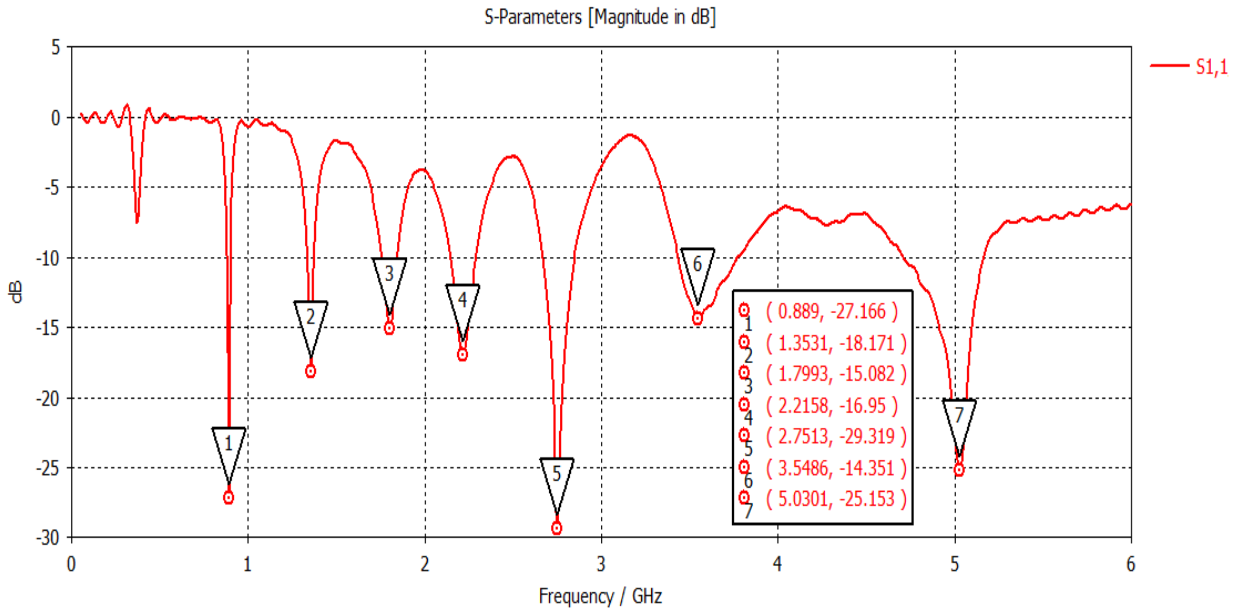

Figure 2: Return loss graph for PIN diode ON condition

Table 2: Performance of the antenna for ON condition

Resonating Frequency (in GHz)	Return Loss (in dB)	Bandwidth (GHz)	VSWR
0.889	-27.16	0.02	1.09
1.353	-18.17	0.05	1.28
1.799	-15.08	0.09	1.42
2.215	-16.95	0.16	1.33
2.751	-29.31	0.19	1.07
3.548	-14.35	0.33	1.47
5.03	-25.15	0.45	1.11

Case-II: When PIN diode is off the antenna resonates at three different frequencies covering S and C band wireless applications. The return loss graph for off condition is shown in figure 3 and Table 3 summarizes the antenna performance for reverse biased condition.

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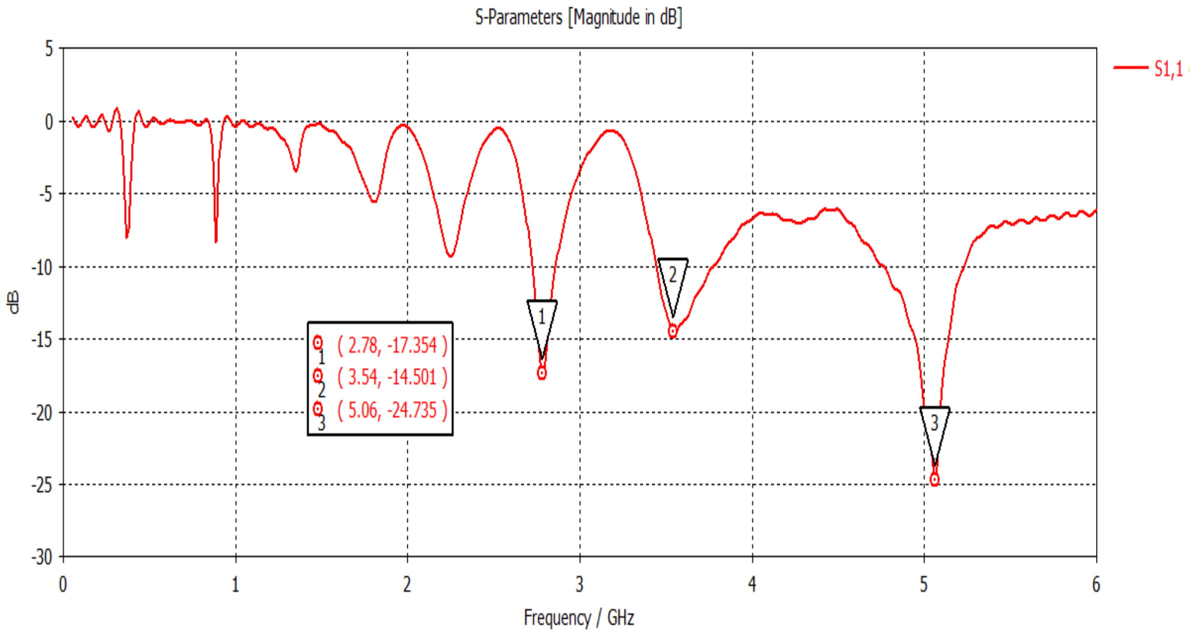
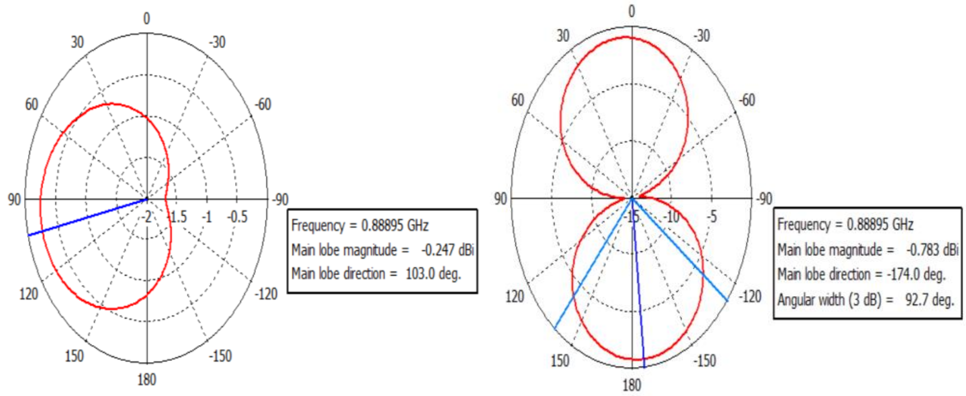


Figure 3: Return loss graph for PIN diode OFF condition

Table 3: Performance of the antenna for ON condition

Resonating Frequency (in GHz)	Return Loss (in dB)	Bandwidth (GHz)	VSWR
2.78	-17.35	0.12	1.31
3.54	-14.50	0.33	1.47
5.06	-24.73	0.46	1.12

The radiation patterns (E-plane and H-plane) for both ON and OFF conditions are shown in figure 4.



(a)E Plane (b)H Plane

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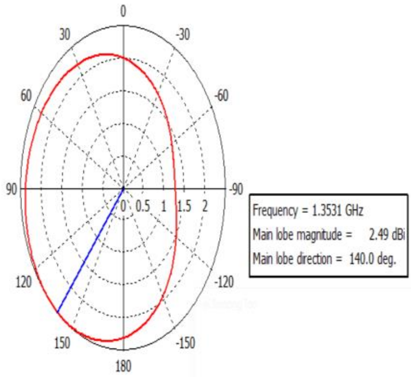
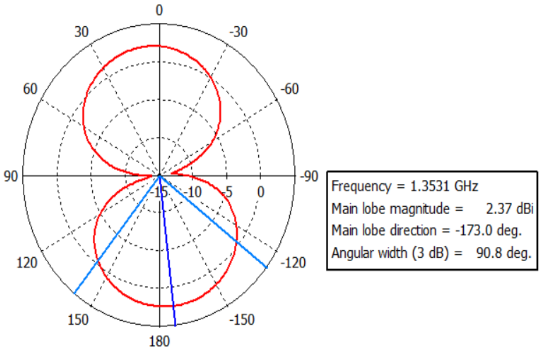
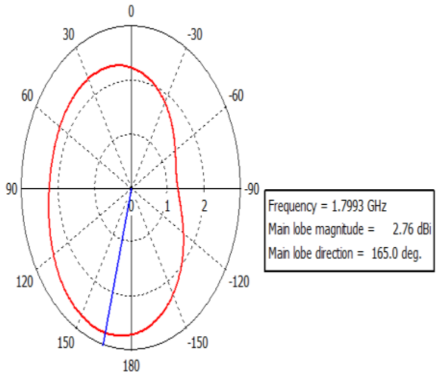


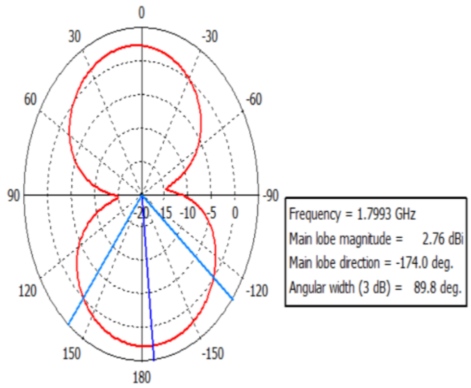
(c)E Plane



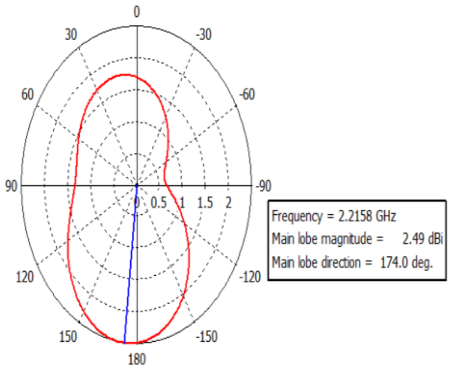
(d)H Plane



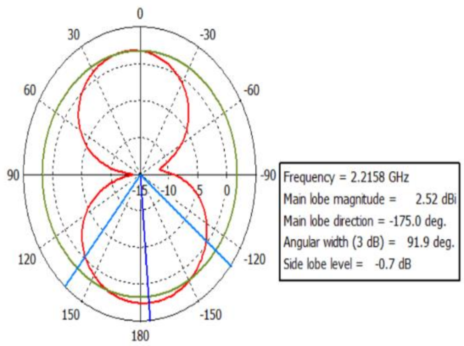
(e)E Plane



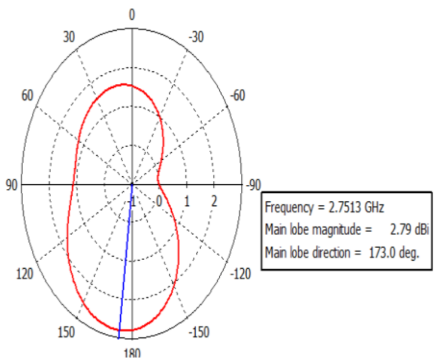
(f)H Plane



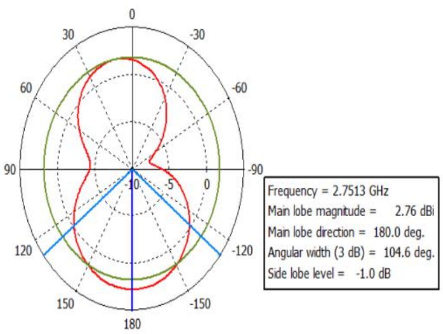
(g)E Plane



(h)H Plane



(i)E Plane



(h)H Plane

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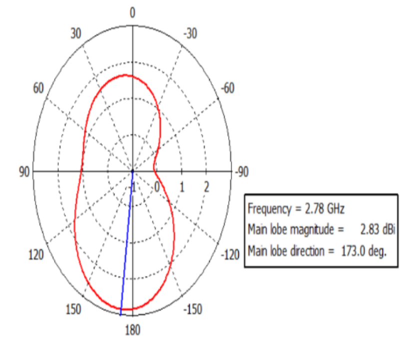
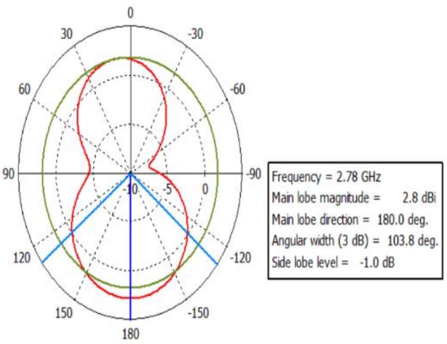
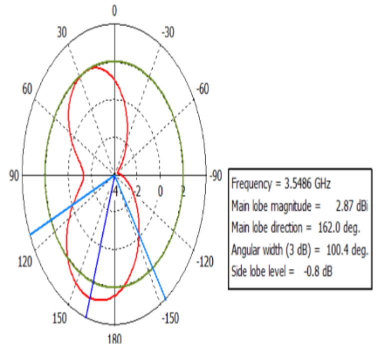


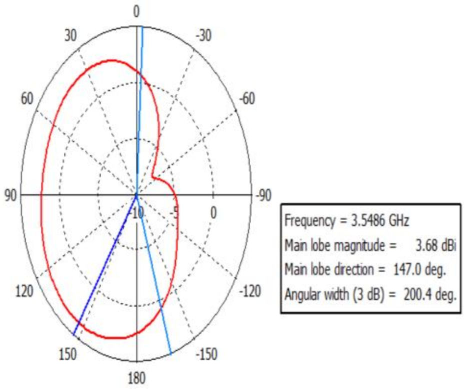
(k)E Plane



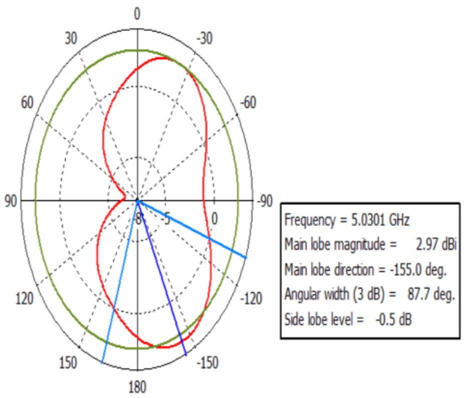
(l)H Plane



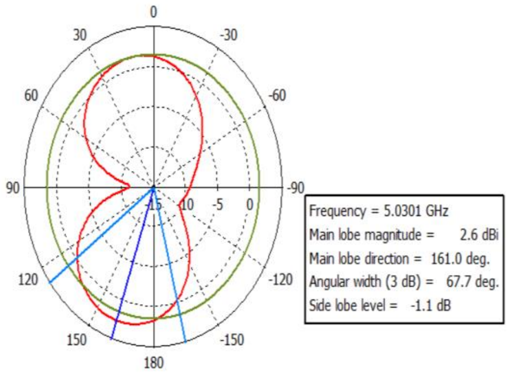
(m)E Plane



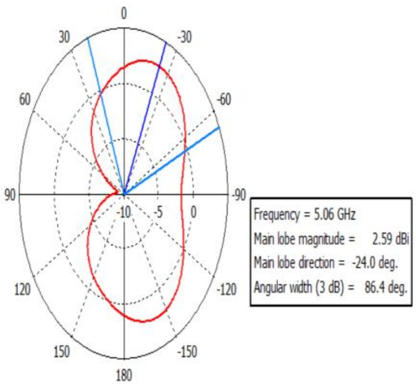
(n)H Plane



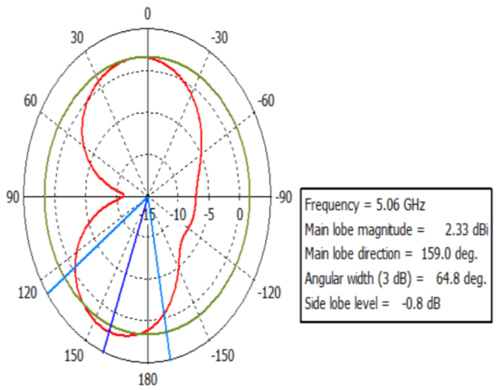
(o)E Plane



(p)H Plane



(q)E Plane



(r)H Plane

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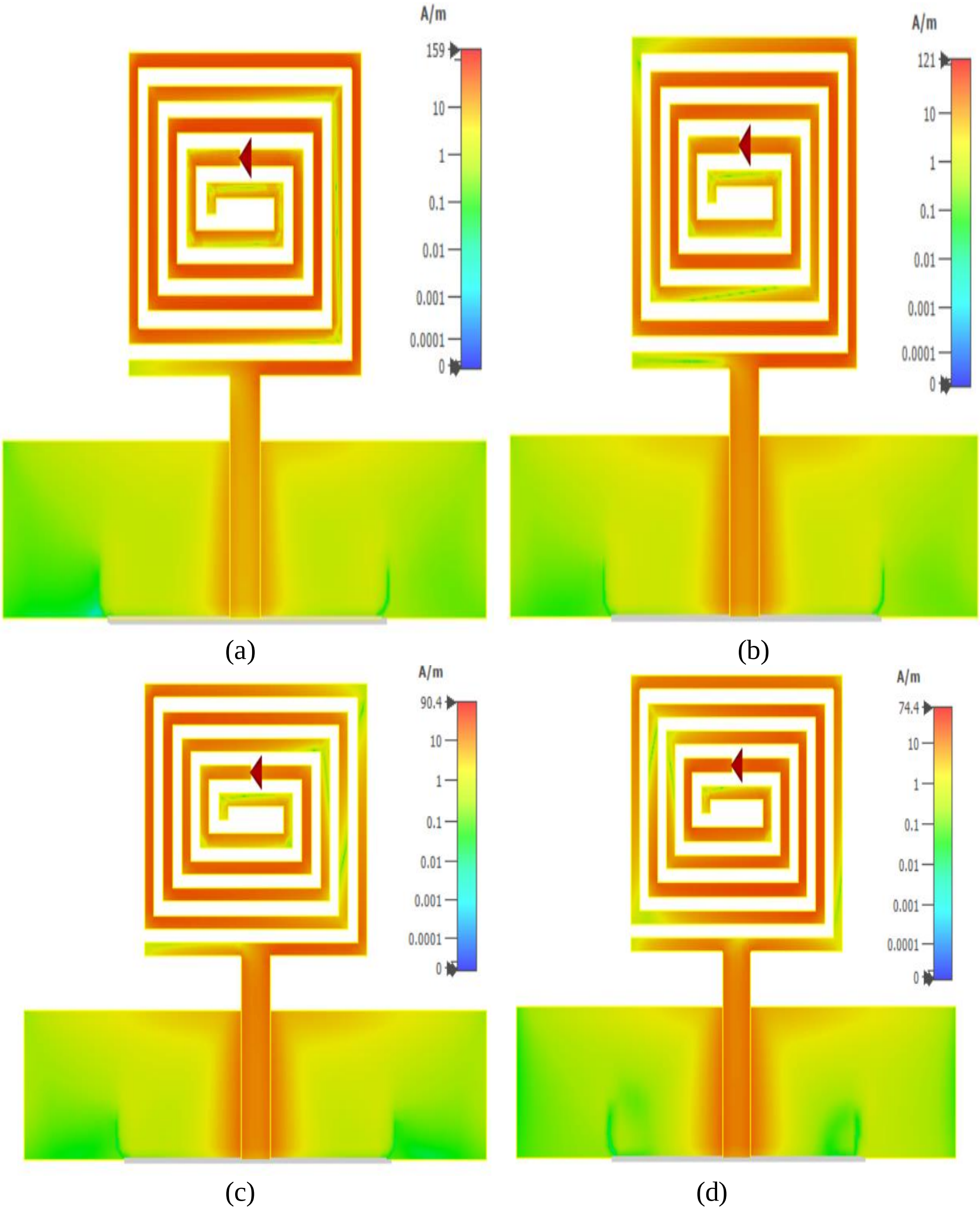
Figure 4: Radiation patterns of proposed antenna for ON and OFF condition: (a) at 0.888 GHz (b) 1.353 GHz (c) 1.799 GHz (d) 2.215 GHz (e) 2.751 GHz (f) 2.78 GHz (g) 3.548 GHz (h) 5.03 GHz (i) 5.06 GHz

Distributions of surface current of the frequency reconfigurable antenna for two cases (Diode ON and OFF) are shown in the figure 5. The effective current path length in the antenna makes the projected antenna to reconfigure at different frequency bands.



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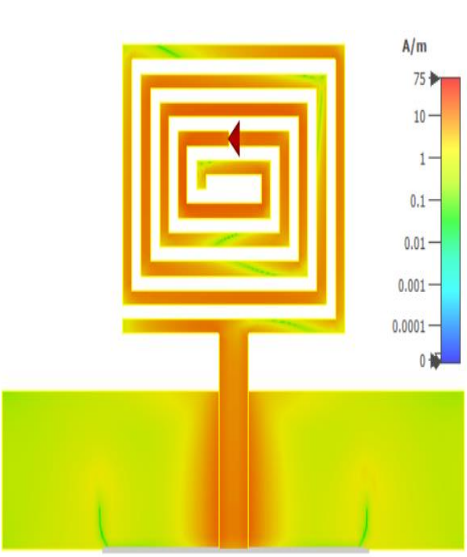
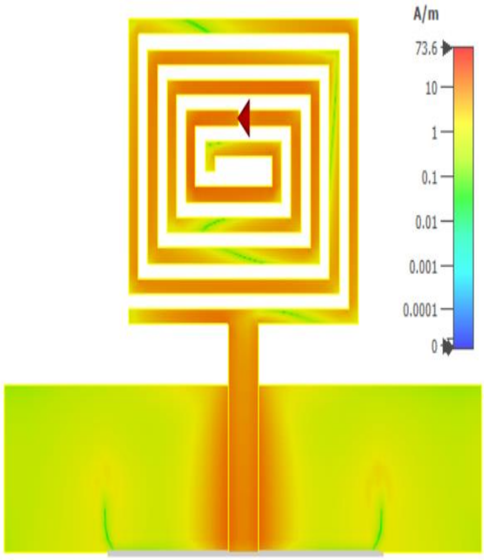


(e)



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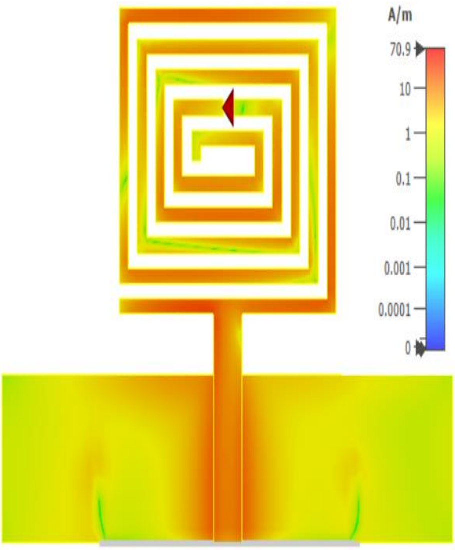
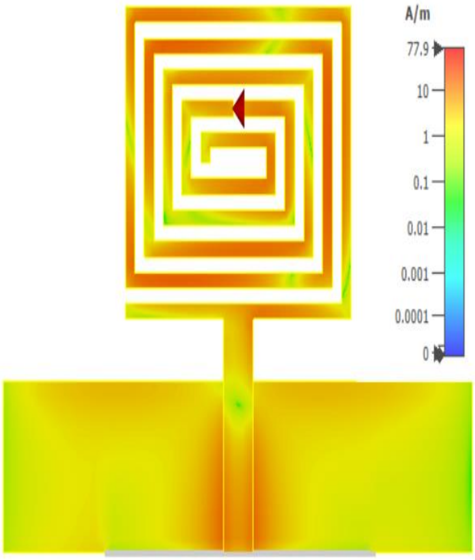


(g)



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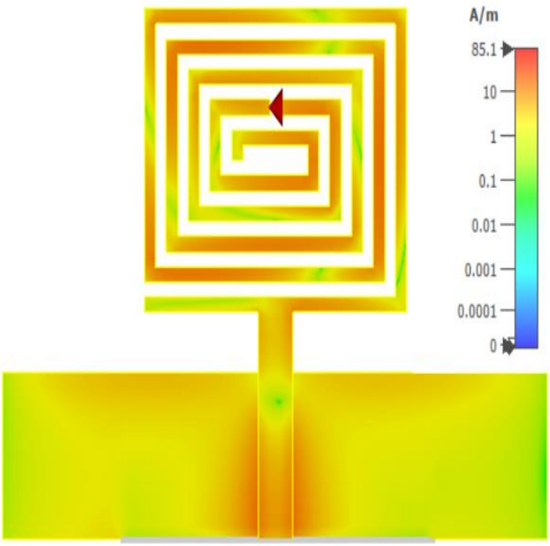

(i)

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Figure 5: Simulated current distributions at (a) 0.888 GHz (b) 1.353 GHz (c) 1.799 GHz (d) 2.215 GHz (e) 2.751 GHz (f) 2.78 GHz (g) 3.548 GHz (h) 5.03 GHz (i) 5.06 GHz

The antenna has a peak gain of 4.66dB. Except at lower resonating frequency band (0.889 GHz) the gain is negative and for other bands it is positive. The gain vs frequency graph for the proposed antenna is shown in figure 6.

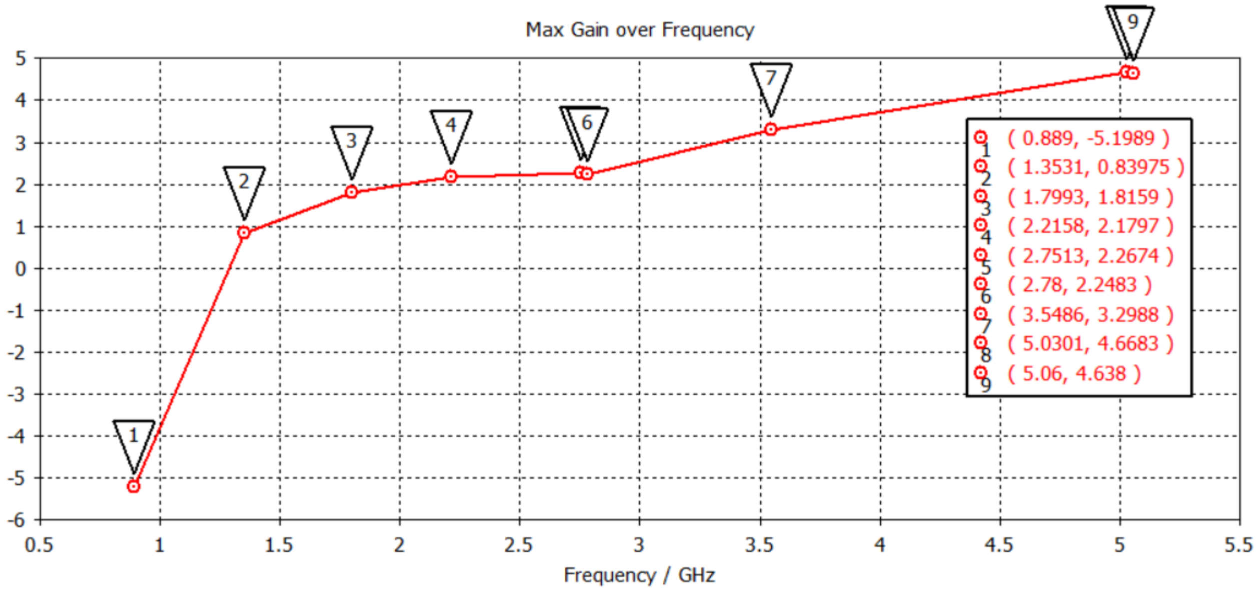

Figure 6: Simulated gain of the proposed antenna.

Comparison with previous works

The present work is contrasted with the recent works in order to demonstrate the superiority of the projected system and to show the novelty in a better way. The table provides a comparison of performance with other structures in terms of antenna area, number of resonant frequency bands, number of switches used, and peak gain. The proposed antenna is advantageous for all of the above parameters, except the antenna area.

Reference	Antenna Size (mm^2)	No. of resonances	No. of switches	Peak gain
[1]	24x20	5	1	3.06
[3]	50x50	9	5	4.8
[4]	50x46	6	5	4.1
[6]	25x27	4	2	2.5
[8]	20x20	3	3	1.9
[9]	73.71x88.59	10	1	-0.2
[10]	31x59	3	1	2
This work	50x50	9	1	4.66

Conclusion

In this paper, a compact and reconfigurable multiband antenna of dimension of $50 \times 50 \times 1.6\ mm^3$ is presented and results are investigated. Partial ground plane and patch is modified into spiral shape. Frequency agility is obtained by inserting single PIN diode into one of the spiral arm. Nine different resonating frequencies are obtained which cover UHF, L, S and C band wireless applications with peak gain of 4.66 dB.

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