Design and Analysis of Multi-Band Met material Antenna for Wireless and IOT Applications

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***Abstract*: This letter presents a design of a metamaterial antenna for different applications in internet of things and wireless networks. The proposed antenna is fabricated on FR-4 epoxy, a substrate with ϵ_r =4.4 with h=1.58 mm and tan δ=0.0035 and the thickness of the metal substance is 35-µm. The dimensions of the antenna are 40×40mm which radiates at multiple bands. Gain of the proposed prototype is 5.1469 db. Various other results are obtained and the antenna upholds its performance for different parameters and results. The prototype is compact, robust and can be taken into consideration for different applications due its multiband nature which makes the antenna a very decent option.**

***Index Terms*: Multi-band antenna, Metamaterial layer.**

I. INTRODUCTION

Radio based LAN'S are increasingly adaptable and also, the greater part of remote neighborhood systems tends to work in the frequencies ranging from 2.4 to 5.85 GHz. Therefore, the antenna required is smaller dual-band antenna. Now days a single antenna is performing many applications so in this case a miniaturized dual-band antenna is required. The prior requirements of these type of antennas are high efficiency and omnidirectional coverage [1]. The meander line technology allows designing antenna which is compact and provides wideband performance [2].

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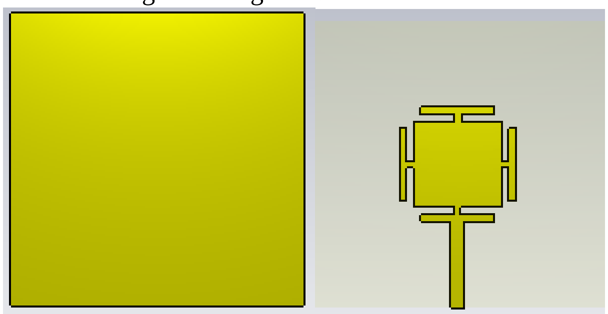
The antennas now a days demands multiple applications hence multiband antennas are also high in demand. Multiband antenna can be designed by adding multibranched strips and etching slots such as U , E and Cover a radiating patch the same purpose can also be served by using feeding techniques like micro strip feed , inset feed , CPW feed. To implement resonant multiband antennas, metamaterial is being used. Metamaterials are of negative permeability and negative permittivity.

Often the antennas with metamaterials, which are of some shapes like square, ring, produce higher resonating frequencies. The antenna, which have ring resonators, provides almost isotropic response. The electromagnetic properties of metamaterials are unique which cannot be found in nature. A single-negative metamaterial shows either negative permeability or negative permittivity. In case both are simultaneously negative then it is called left-handed or double negative metamaterial. Metamaterials are also classified into X-shaped, S-shaped and H-shaped. The metamaterials used in this antenna is square shaped to obtain unique electro-magnetic properties. The microwave metamaterials are of alumina and stealth materials, they are composed of periodic arrays of subwavelength metallic elements. The metamaterial absorbers have high absorption properties through dielectric loss and impedance matching at resonators [3]-[6]. With the need of wireless communications, the concentration towards developing antennas for wireless applications is amplified. IEEE 802.1 can provide data rates ranging in between 11 Mbps to 108 Mbps. The operable bands range as 2.4 -2.4385 GHz, 5.150-5.250 GHz, and 5.725-5.825 GHz. These frequency ranges are mainly used in laptops and embedded devices. There are different approaches proposed to realize dual-band antenna such as Slot, Shorting pin, different dimensions of pole are some of the prominent proficiencies to operate an antenna in dual-band. Metamaterial elements like Split Ring Resonator, Thin Wire, Complementary SRR and Complementary TW are used to obtain the function of metamaterials perfectly [7]-[8]. Some of the achievements of metamaterials are holographic surfaces to squeeze tailored radiation pattern out of it to create circular polarization or to increase the gain of simple radiating elements, such as dipole antennas, which allows multi frequency and spatial diversity operation. Metamaterials can also work to improve the radiation pattern of antennas [9]-[10]. The reconfigurable antennas are very crucial now days. Frequency is the main property for any antenna. The frequency reconfigurable antennas are used to obtain the working capacity of antenna in multiple frequencies.

The mechanism used is Frequency reconfiguration by metamaterials. Metamaterials make antenna to work in multiple frequencies through resonators. There are two types of frequency reconfigurable antennas continuous and switched. The antennas, which provide smooth transition between frequency bands, are continuous frequency antennas. In contrast, switched tunable antennas allow operating at distinct frequency bands [11]. The Fractal sieprinski model is used in this antenna which have different slots like triangular, rectangular, square and hexagonal. The proposed method is rectangular slots. Here both rectangular slot antenna regarding sieprinski model and minkowski model are combined and implemented [12]. The metamaterials are added for the miniaturization of antenna and for improvement of antenna matching. Reconfigurable antennas are well known for their power saving capacity. Two models are designed and fabricated. In the second model, the metamaterial load is made by some junction at the first metamaterial. Both the models are essential, so they are fabricated and the results were also confirmed with simulations. The efficiency of metamaterials is observed on return loss and current distribution. The techniques used to obtain permittivity and permeability of the metamaterial layer are transmission and reflection. [13]-[14].

II. ANTENNA DESIGN

The rectangular sieprinski fractal slot antenna is proposed in this letter. The prototype antenna is designed from the iterations given in figure1 and the results are shown in figure 3. Iteration one is a basic rectangular patch antenna with a square shaped ground and T shapes attached to it. The second iteration has a patch with six square shaped slots and a symmetrical double H shaped slot. The third iteration is the proposed antenna which gives the desired output compared to the other two iterations. The sieprinski antenna is designed with metamaterial loads including in it. The main resonances are obtained by metamaterial layer and also the reasons for fractal sieprinski to use metamaterial layer is to improve antenna matching and also the bandwidth. The minkowski fractal is used to increase the effective area of antenna and also the effective length of metamaterial layer to achieve higher bandwidth. The antenna is printed on FR-4 low cost substrate where ϵ_r =4.4 with h=1.58 mm and tan δ=0.0035. The thickness of metal substances is 35-μm. The size of antenna is 40×40mm. The proposed antenna and its parameters are given in figure 2.



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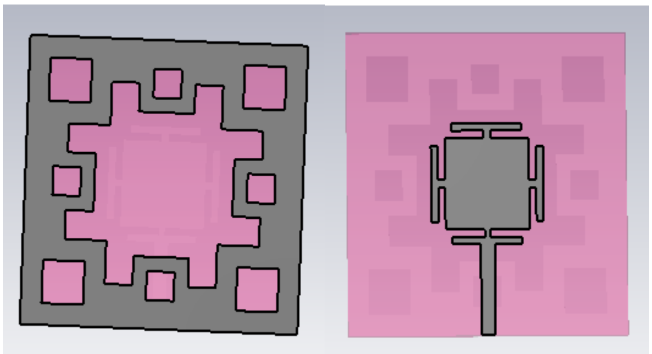

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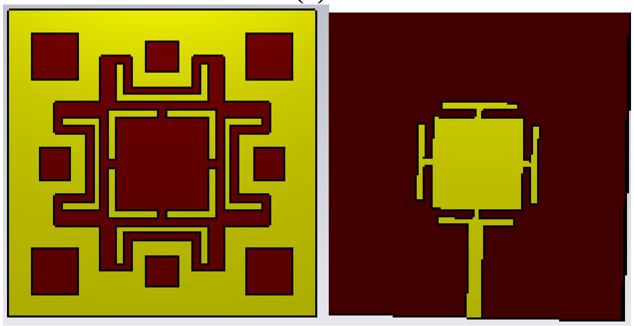
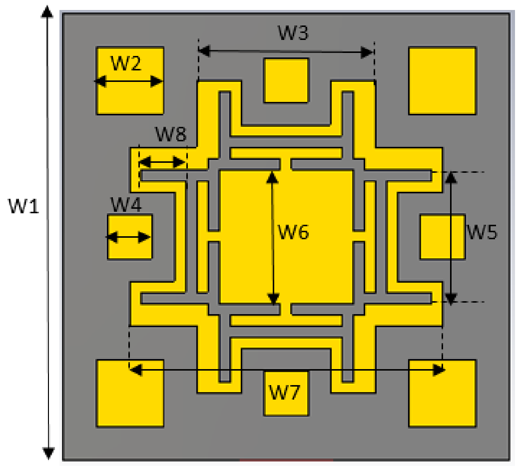


(c)

Figure 1(a) Iteration 1 (b) Iteration 2 (c) Proposed Antenna

TABLE 1: Dimensions of the patch.

W1	**40 mm**	**W5**	**12 mm**
W2	6 mm	W6	12 mm
W3	16 mm	W7	28 mm
W4	4 mm	W8	5 mm



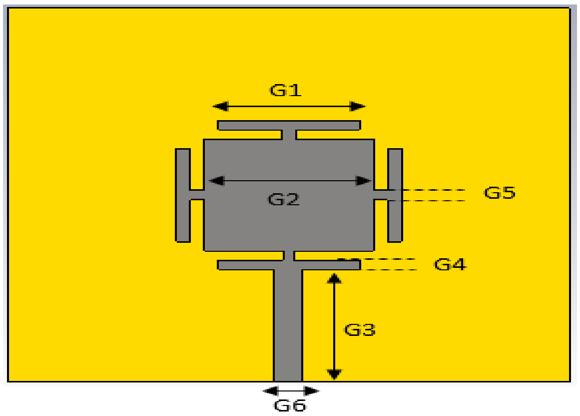
(a)

TABLE 2: Dimensions of the ground.

G1	**10 mm**	**G4**	**1 mm**
G2	12 mm	G5	1 mm
G3	12 mm	G6	2 mm

(b)

Figure 2 (a) The Geometry of Antenna patch (b) The Geometry of Antenna Ground.



III. RESULTS AND DESCUSSIONS

The outputs of the different iterations given in figure 1 are obtained and is shown in the figure 3. The first iteration obtains its result at 7.5GHz which is not the output desired and so the second iteration is designed which is also does not obtain a multi band signal which is the main objective behind this letter. So in the next iteration the required multiband is obtained and also satisfies different applications which the prototype is expected to satisfy.

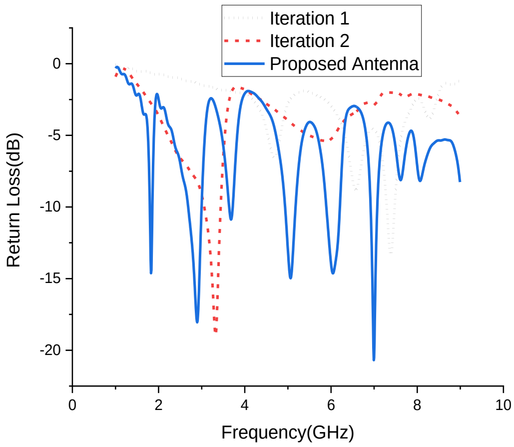


Figure 3 Results Of the iterations

A. PARAMETRIC ANALYSIS

Two main parameters of the proposed antenna are found to have greater impact on the return loss of the antenna. The two parameters take here are W1 and W6. W1 is the length of the entire patch and W6 is the length of the side of the central square. When W1 is 39mm or 40mm the return loss didn't vary much and hence w1=40mm is taken as optimum measurement. But when w1 is more than 40 the return loss obtained is not satisfactory. When W6=12mm four operating frequencies are obtained but the return loss is not up to the mark. When W6 =11mm the return loss is noticeably increased but still roughly maintaining the same operational frequencies when W6=12mm. but, when the W6=10 the antenna began to function is dual band and hence the optimum value for W6 is 11mm. The parametric analysis for variation in W1 results are simulated and shown in figure 4 and the parametric analysis for variations in W6 results are simulated are shown in figure 5.

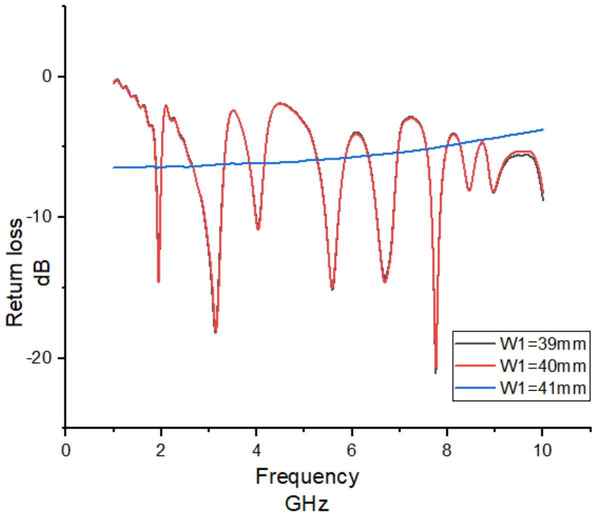


Figure 4. The return loss of the proposed Antenna with different values of W1

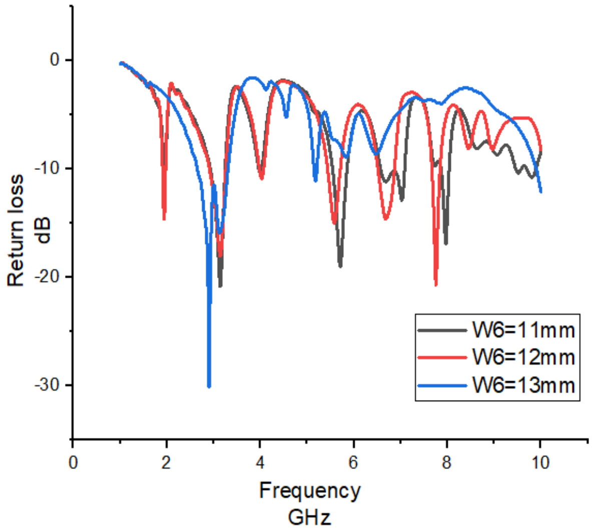


Figure 5. The return loss of the proposed Antenna with different values of W6

B. Return Loss

The proposed sieprinski fractal slot antenna has a unique way of operation. It has six resonant frequencies due to the special designs of the patch and the ground. The resonant operating frequencies are 1.93GHz, 3.142GHz, 4.0235GHz, 5.5773GHz, 6.679GHz and 7.7464GHz with return losses of -14.62dB, -18.04dB, -10.874dB, -14.966dB, -14.624dB and -20.316dB respectively. The above-discussed return loss values versus frequencies both experimented and simulated are depicted in the figure 6.

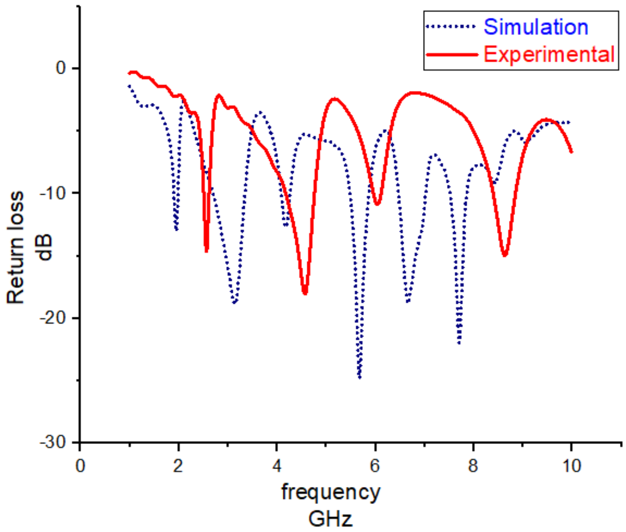
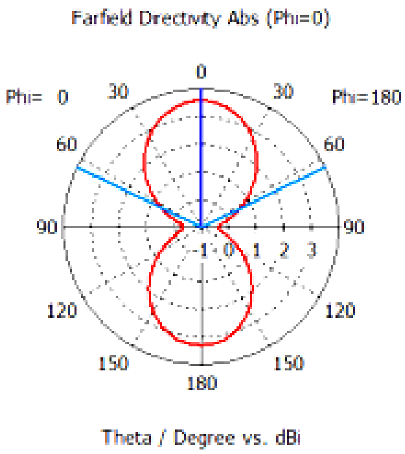


Figure 6. The return loss of the proposed Antenna with both simulated and experimented results.

C. Radiation Patterns

The proposed antenna radiation pattern is simulated in the CST studio environment for the frequencies 1.5 GHz, 1.936 GHz and 2.5 GHz. This antenna is having bidirectional radiational pattern in E-plane (phi=0^0) and the antenna exhibits omnidirectional pattern in H-plane (phi=90^0) but sometimes the antenna also possesses bidirectional radiation pattern in H-plane too. This proposed antenna is almost having omnidirectional radiation pattern and the antenna shows miniature variations in its radiation pattern above 5.5GHz frequencies. The radiation patters od the proposed antenna at three frequencies 1.5 GHz, 1.936 GHz and 2.5GHz in the figure 7.



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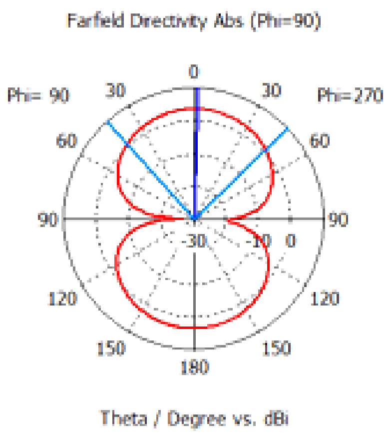

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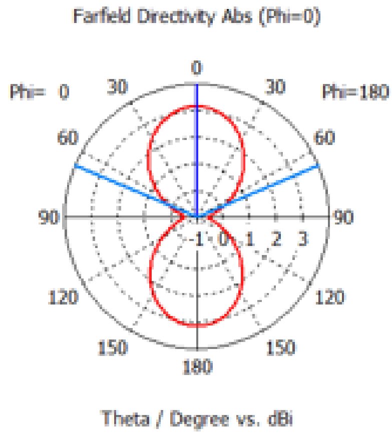

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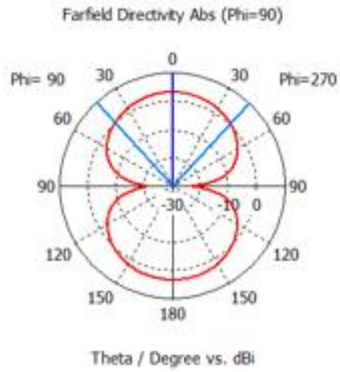

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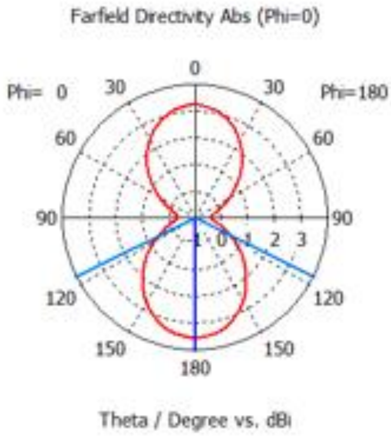

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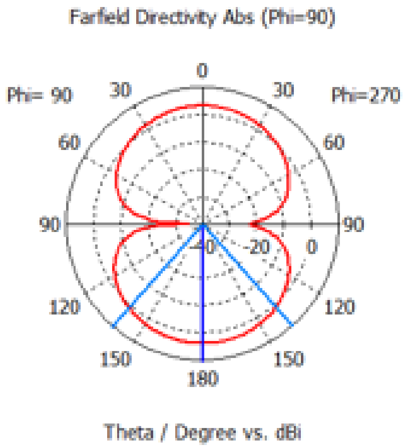


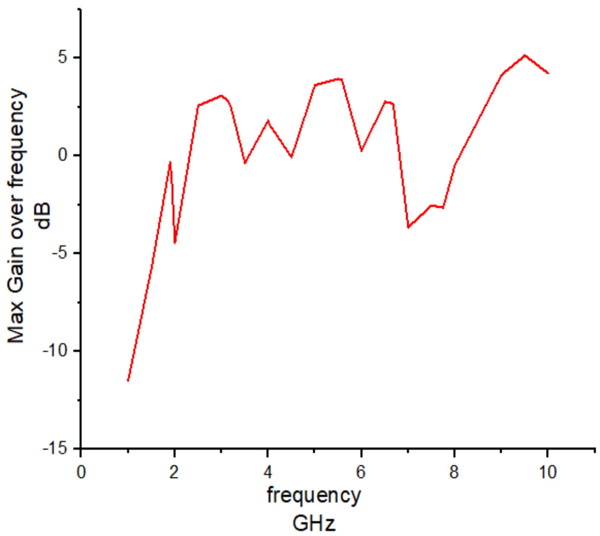
(f)

Figure 7. The simulation of antenna radiation pattern (a) the antenna at 1.5 GHz in E-plane (phi=0°) (b) the antenna at 1.5 GHz in H-plane (phi=90°) (c) the antenna at 1.936 GHz in E-plane (d) the antenna at 1.936 GHz in H-plane (e) the antenna at 2.5 GHz in E-plane (f) the antenna at 2.5 GHz in H-plane

C. Gain

The gain of an antenna shown how far the energy of an antenna is transmitted in the form of radio waves. It is also one of the deciding parameters of an antenna design. The figure 8 shows the gain of the proposed antenna in different frequencies and it is observed that the maximum gain is at 9.5 GHz with a gain of 5.1469 dB.

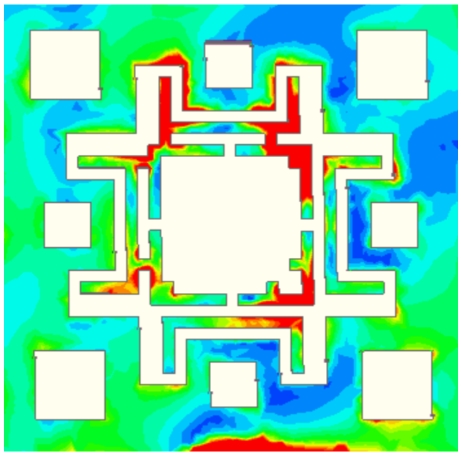
Figure 8. The simulation of Max Gain over



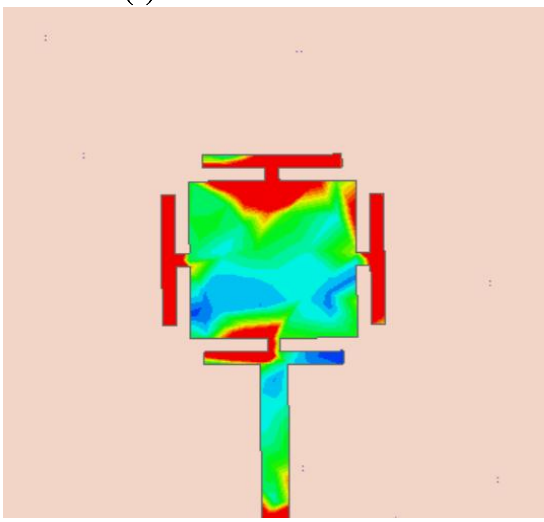
frequency for proposed antenna.

D. Current Density

The current distribution on the surface of the antenna is simulated as shown in the figure 9 and figure 10. It clearly shows how the current is dispersed on the surface of the antenna. So here two cases of frequencies namely 1.95GHz and 7.7GHz are considered and simulated. These results clearly show that for the frequency of 1.95GHz. Most of the current distribution is present at the center of the patch and the left half of the ground is also having maximum current distribution as shown in figure 9. For 7.7GHz frequency, the maximum current distribution is found at the lower part of the patch and in the ground plane most of the current is present in the shape of the fan producing out from the central ground square towards the sides of the substrate as shown in figure10.



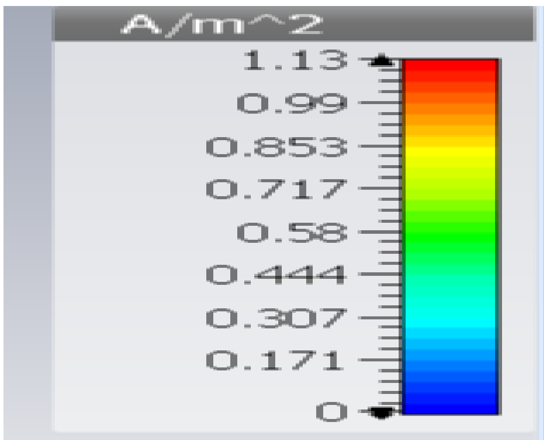
(a)

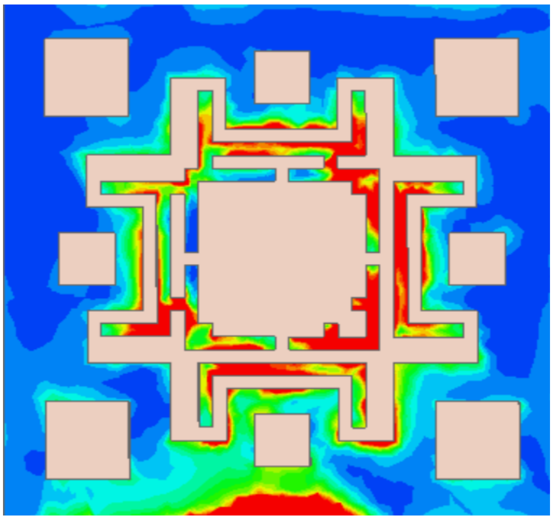


(b)

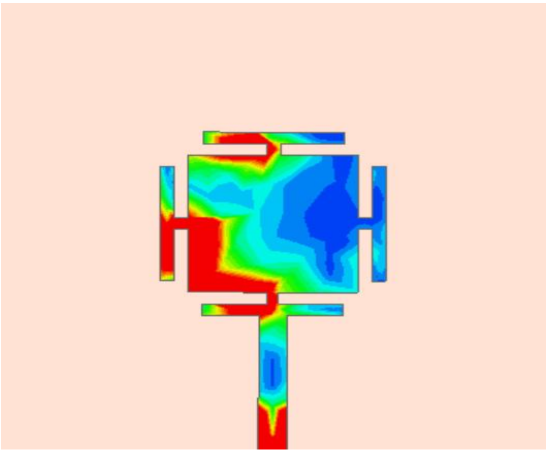
(c)

Figure 9. The antenna current distribution at 1.9 GHz (a) on the patch and (b) on the ground (c) surface current distribution.





(a)



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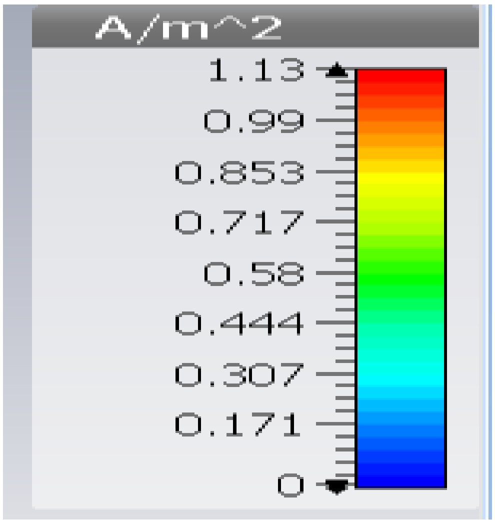
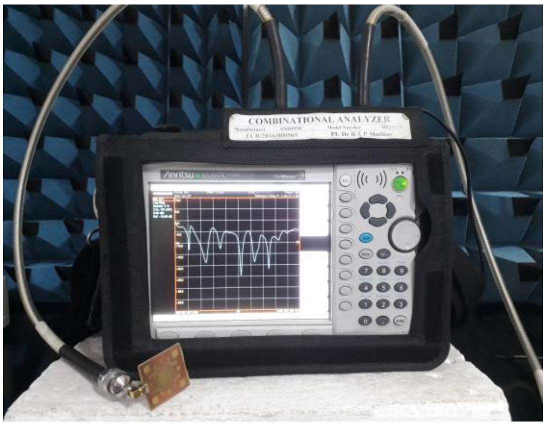


(c)

Figure 10. the antenna current distribution at 7.7 GHz (a) on the patch and (b) on the ground (c) surface current distribution.



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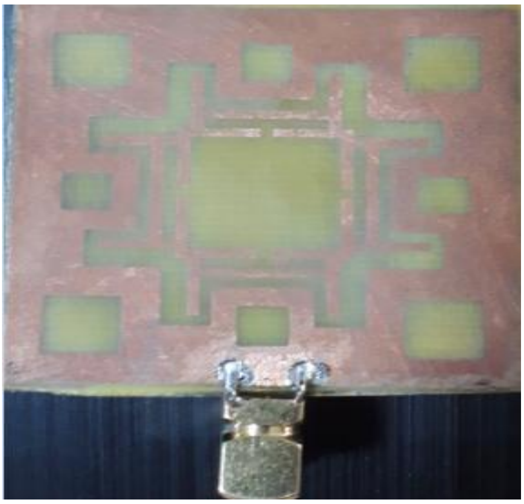

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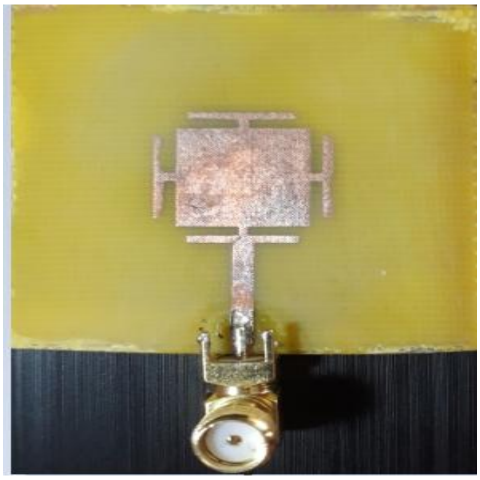

(c)

Figure 11 (a) The Experimental setup of the proposed antenna (b) Top side of fabricated antenna (c) Bottom side of fabricated antenna

The measured analysis and simulated analysis are in synchronization with each other which proves that the prototype is very effective. This is also proved from table 3 where different recent works have been considered but the proposed antenna proves to be more considerate to others.

TABLE 3. The comparison between the reference antennas with the Proposed antennas.

Reference	Dimensions(mm)	Frequency	Gain
1	30.6 x 3.6 x3.6	5.4 GHz	1.5 & 2.19 dB
2	25 x 22 x 1.6	5.8 GHz	1.98 dB
3	45 x 13 x 20	2.4 GHz	0dB
4	30 x 18 x 1.5	5GHz ,6GHz & 7GHz	0 dB
5	55 x 65 x 20	2.4 GHz ,5.1 GHz 5.72GHz & 5.8GHz	0dB
Proposed antenna	40 x 40 x 1.6	1.936GHz, 3.142GHz, 4.02345GHz, 5.5777GHz, 6.679GHz & 7.7467GHz	5.1469dB

IV. CONCLUSION

Herein, the proposed Sieprinski fractal slot antenna functions in multiband frequencies therefore this antenna can be utilized in many communication technologies like Wi-Fi, WiMAX and WLAN. The parametric analysis is also performed and analyzed in this paper. This antenna has a compact size as shown in the table 3 where the number of operating frequencies and the gain of the proposed antenna is higher than the reference antennas. Also, the proposed antenna functions in multiple frequencies unlike other reference antennas which have either single frequency or dual frequency of operation.

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