International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 06, June-2021

A Compact Hybrid Fractal Antenna using Koch and Minkowski Curves for Wireless Applications

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***Abstract*: A compacted Hybrid Fractal multiband antenna using Koch and Minkowski Curves proposed in this paper for wireless applications. The Hybrid Fractal techniques is used to miniaturization of antenna. Koch curve improves the impedance bandwidth. Minkowski fractal curve gives its contribution to make antenna multiband. By adding the Circular SRR structure at side of Hybrid fractal patch antenna to improve both gain and bandwidth. It has compact size is 34 mm × 34 mm × 1.6 mm^3. The suggested antenna has been design on FR4 substrate with εr =4.4 with 1.6 thickness. The proposed antenna resonates at four frequencies 2.48GHz, 3.16GHz, 4.80GHz, and 5.64GHz. The bandwidth of antenna getting 160MHz, 85MHz,100MHz and 220MHz at 2.48GHz, 3.16GHz,4.80GHz and 5.54GHz respectively. The peak gains of the proposed antenna in these frequency bands vary from 4.0 to 6.5 dBi. All the four band has VSWR less 1.6.**

Keywords— Hybrid Fractal, Multiband, Minkowski fractal, SRR, and WLAN.

I. INTRODUCTION

Currently, wireless communication system has played a very significant role in our day-to-day life. Therefore, antennas premeditated for wireless applications have fascinated considerable attention from investigators and academics around the globe. Multi-frequencies antennas devices can offer many receptions and transmission functionalities. It is consequently considerable wanted to have a single antenna by means of a single feed point that covering several different frequency bands. The premeditated antennas are predictable to be solid small and easy to handle and can be well combined with several telecommunication devices. The fabricated antenna is famous for its compression size, not expensive, comfort to industrial and effortlessness of incorporation with other circuits [1-3].

In WLAN and WiMAX communication system, the antenna has been considered as the main part because its performance will straightly influence on the excellence of the wireless communications. Furthermore, the best antenna is the antenna that can be handle many applications by using only a single substrate to reduce the size used. In recent years, some multiband for WLAN and WiMAX applications have projected to design.

The compactness practice is one of the most appropriate trends for wireless devices as it develops resulting future generation of antennas for these applications which desired in numerous frequencies focused. In other hand, the fractal geometry also is one the favorite technique used that permits us to strategies a small antenna that easy to integrate multiple telecommunication services into single devices.

There are several designs that apply the Minkowski fractal patch antenna such as in this paper of Hota. In his paper, the Minkowski patch effect to create the multiband effect to the antenna compare with the basic geometry design. This antenna achieves the resonant frequency at 6.32 GHz, 7.048 GHz, 8.448 GHz, 9.176 GHz, 9.68 GHz, 10.856 GHz and 11.92 GHz, respectively [4]. In other work, Dalmiya had been propose a Minkowski fractal antenna to create a multiband effect at several operating frequencies at 8.8 GHz, 10.8 GHz, 13.02 GHz and 15.23 GHz with reflection coefficient - 17.224 dB, - 22.604 dB, - 15.675 dB and - 36.072 dB, respectively [5]. Nelaturi in 2016 had been design a compact Minkowski fractal antenna with high impedance surface (HIS) structure that effect dual resonant frequencies with bandwidth of 13.01 % and 4.95 %, respectively [6]. Lastly, dual band antenna had been exist effected by the Minkowski fractal structure. This antenna resonates at 1.228 GHz and 1.5745 GHz. This Minkowski structure also effect to reduce 38 % of size compare with the basic patch antenna design [7]. Shafie in his design had been introduce a modified Minkowski fractal antenna that creates a tri-band application at WiMAX 2.3 GHz, Wireless LAN 2.45 GHz and Hyper LAN 5.2 GHz [8]. Suganti in his paper also used the same technique for his planar Minkowski fractal antenna that effect to resonate at 4.8 GHz, 6.0 GHz and 8.0 GHz [9]. Beside that, there are others work of antenna that apply this Minkowski fractal structure in this several papers of [10-12].Meanwhile the metamaterials were introduced, academically categorized, and experimentally realized, previous researcher and engineers have exasperated several methods to bring these special features characteristics into applied application. Split ring resonator (SRR) is one of the examples metamaterial structure that used to the antenna design. There are not many examples previously on the antenna design that apply rhombic structure of SRR.Basically, before this, the researcher is using the basic structure of edge-couple SRR or other SRR structure [13-15].

In this work, the multi-band hybrid fractal patch antenna with Circular SRR has been functioning in four different frequencies at 2.46 GHz, 3.18GHz, 4.80GHz and 5.60 GHz for WLAN and WiMAX application. The methods apply in this paper are Minkowski fractal patch structure with circular SRR on the substrate.

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II. ANTENNA CONFIGURATION

This section focusses on the simulation design comprises with the basic structure of circular SRR and lately of the Minkowski-Koch hybrid fractal patch with circular SRR. This design is simulated using HFSS Software. The circular SRR has been attached at the upper part of the FR-4 substrate. The position of this circular SRR is at every corner of the Minkowski-Koch hybrid fractal patch antenna. Figure 1 show the circular split ring structure and Table I shows the structure of circular SRR with its dimension. The radius of the circular SRR at inner ring is R2=2.0 mm and outer ring are R1=3.0 mm. The gap amongst SRR is 1.00 mm.

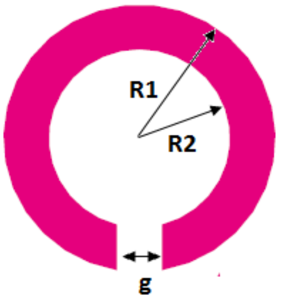
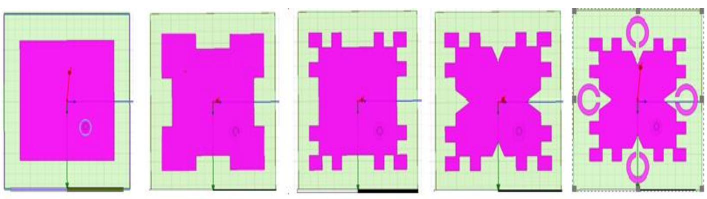


Fig.1.The SRR using circular structure

Figure 2 iteration-wise stage of the Minkowski-koch Hybrid fractal patch antenna. These five stages that founded are - iteration 0th, iteration 1st, iteration 2nd, iteration 3rd and iteration 3rd with SRR.The length of patch (L) at resonant frequency of 3.4GHz has been calculated by using the below equations.

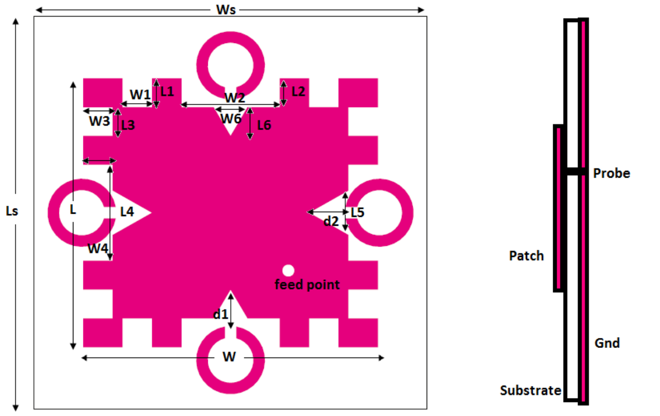
$$L = \frac{\lambda_0}{2\sqrt{\varepsilon_r}} \quad \text{---(1)}$$



(a) (b) (c) (d) (e)

Fig. 2. Design steps of the multiband Hybrid Fractal antenna
(a) 0th iteration (b) 1st iteration (c) 2nd iteration (d) 3rd iteration (e) 3rd iteration with circular SRR

This proposed Minkowski-Koch hybrid fractal patch antenna with circular SRR has been design on substrate of FR-4 with dielectric constant, εr = 4.4. The dimension substrate of the proposed hybrid fractal antenna with circular SRR is 34.0 mm substrate width and 34.0 mm substrate length. The thickness of this substrate is 1.6 mm. The copper cladding thickness for patch and ground plane is 0.070 mm. The proposed Minkowski-koch hybrid fractal patch antenna with circular SRR as illustrated in Figure 3.



(a) (b)

Fig.3. Geometry of the proposed Hybrid Fractal multi band antenna (a) Top View (b) Side View

Table I displays the optimized dimension of the Minkowski-koch hybrid fractal patch antenna. In this case, this design containing of three different parts - Minkowski-koch fractal patch, feed point and circular SRR. The Minkowski-koch hybrid fractal patch antenna part has been situated at the above part of feed line. The size of this part is 23.0 mm width x 25.0 mm length. The feed point location is (X=5,Y=5).

Table 1: Optimized Parameter Values

Parameters	Dimension (mm)	Parameters	Dimension (mm)
Ls	34	Ws	34
L	23	W	25
L1	2.5	W1	2.5
L2	2.5	W2	8.5
L3	2.6	W3	2.6
L4	2.5	W4	8.3
L5	3.9	d1	2.4
L6	2.3	W6	2.5
g	1.0	d2	3.0
R1	3.0	R2	2.0

III.RESULTS AND DISCUSSION

This section shows otherwise performance results of proposed hybrid fractal antenna structure. Several constraints that are measured in this effort are resonant frequency, Return Loss, VSWR, bandwidth and gain of the antenna.

Figure 4 illustrate the return Loss of Minkowski fractal patch antenna with circular SRR structure. Firstly, it conclude that for zero iteration is at 3.38 GHz of resonant frequency with -12.91 dB of return loss. The resonant frequency of first iteration shifted to lower side at 3.24 GHz frequency with -19.67 dB of return loss. The second iteration got two frequency are 2.88 GHz, 3.70 GHz with a respective return Loss of -32.48 dB, -21.42 dB. The final design has been done in third iteration with SRR. The three resonant frequency of 3rd iteration design are at 2.60 GHz, 3.32 GHz and 5.82 GHz with -19.54 dB, -18.05 dB and -14.15 dB.

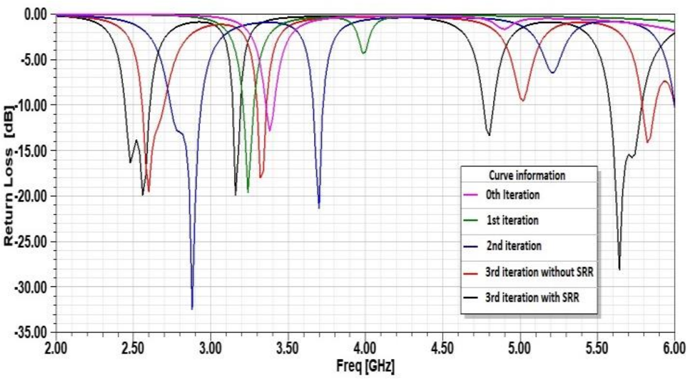


Fig 4: Simulated return loss characteristics of iteration-wise fractal antenna

Finally By circular SRR added to the 3rd iteration design, it develops a new resonant frequency at 4.80 GHz equated to the third iteration without SRR that only have only three resonant frequencies. The graph clearly represents the different type of stage will control where the resonant frequency.

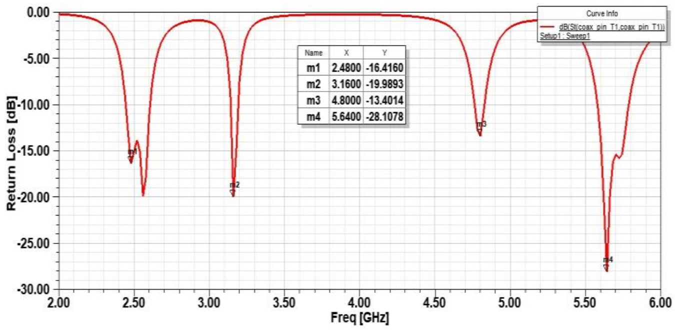


Fig 5: Simulated return loss of proposed fractal multiband antenna

From Figure 5 shows the return loss of proposed fractal multiband antenna. It can observed that four resonant frequency are at 2.48 GHz, 3.16 GHz, 4.80 GHz and 5.66 GHz with values are -16.41,-19.98 dB, -13.40 dB and -28.10 dB respectively. Hybrid Fractal plays significant role in achieving multiband frequency characteristics.

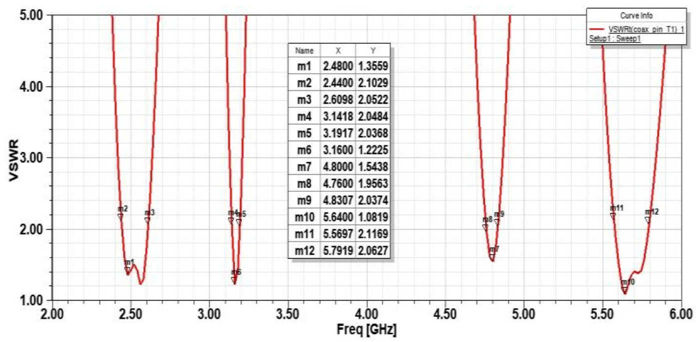


Fig 6: Simulated VSWR of proposed fractal multiband antenna

Figure 6 shows that VSWR of proposed fractal antenna, it is found that the VSWR value is 1.35, 1.22, 1.54 and 1.08 at freq of 2.4 GHz, 3.1GHz, 4.8GHz and 5.6GHz with bandwidth 160MHz, 85MHz, 100MHz and 220 MHz respectively.

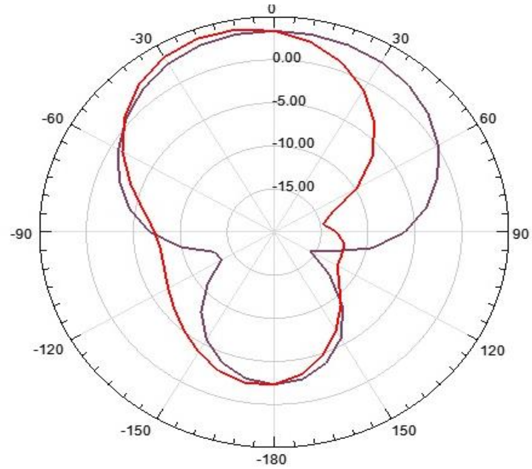
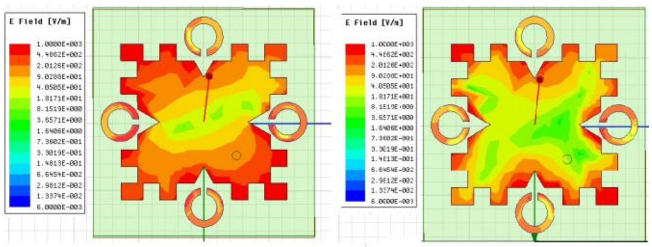


Fig. 7. Radiation Patterns of proposed antenna at (a) 2.45 GHz

The figure 7 (a) shows Radiation Patterns of proposed antenna at 2.45 GHz in E and H-plane. Here, the simulated radiation pattern in H Plane and E plane is directional radiation Pattern in both Planes for all bands.



(a) (b)

Fig.8 Surface current distributions (a) 2.45GHz (b) 5.65GHz

The current distribution of the proposed fractal multiband antenna at 2.45 GHz and 5.65GHz is presented in Figure 8. It can be seen that strong surface currents are distributed over the edge of patch antenna.

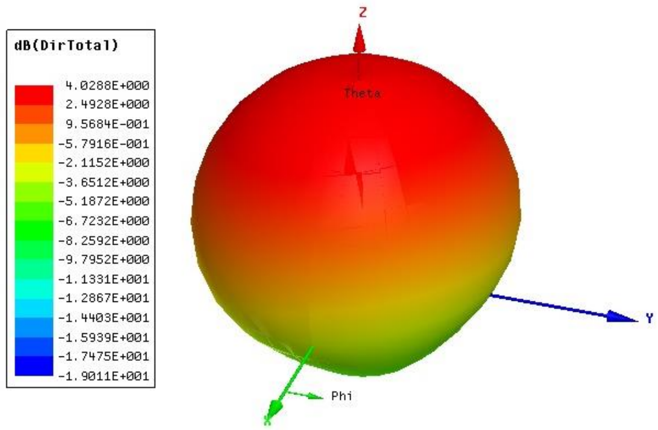


Fig. 9. 3D Gain of the proposed Fractal antenna at 2.45GHz

Table II characterize the Return loss, resonate frequency and other parameters from 2.0 GHz to 6.0 GHz frequency range of proposed antenna (0th iteration, 1st iteration, 2nd iteration, 3rd iteration without CSRR and 3rd iteration with CSRR). The third iteration without CSRR shows the low bandwidth and gain performance all freq bands. It shows that in third iteration with CSRR, it added fourth frequency band. Also effect to increase the both bandwidth and gain of the proposed hybrid fractal patch antenna. The gain value is increased up to 0.8dB all frequency bands.

Sr .N o.	Shape of MSA	Freq (GHZ)	Return Loss(dB)	VSWR	Bandwidth (MHZ)	Gain (dB)
1.	0th iteration	3.40	-12.91	1.20	120	4.9
2.	1st iteration	3.24	-19.67	1.23	80	4.0
3.	2nd iteration	2.88	-32.48	1.04	210	3.4
		3.70	-21.42	1.18	90	2.4
4,	3rd iteration without CSRR	2.60	-19.54	1.23	150	3.2
		3.32	-18.05	1.28	75	2.0
		5.82	-14.15	1.48	100	2.8
5.	3rd iteration with CSRR Proposed fractal	2.48	-16.41	1.13	160	4.0
		3.16	-19.98	1.22	85	4.3
		4.80	-13.40	1.54	100	4.6
		5.64	-28.10	1.08	220	6.5

Table 2: Comparison Table of Antenna Evolution Process

IV. CONCLUSION

A compact antenna with multiband characteristic is designed using hybrid fractal with SRR technique for Wireless Applications. The performance characteristics of proposed hybrid fractal antenna are sound as compared to single curve fractal antennas. The overall size of antenna is very small $34\times34\times1.6$ mm^3. From the simulation, it shows that the Hybrid Fractal Antenna has been produced a Multiband of resonant frequencies at 2.48 GHz, 3.16 GHz,4.80 GHz and 5.64 GHz.The third iteration with circular SRR design successfully to enhance the gain equated with third iteration design. The mixture of the fractal geometry and SRR had been making the size antenna reduced, gain amended and produce multiband of frequency. Proposed antenna resonates at multiband frequencies and its Radiation pattern is stable all the four frequency bands with good gain. The proposed fractal antenna can be used for various applications like Bluetooth, Wi-Fi, WLAN, LTE and WiMAX.

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