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Energy Efficient Multi Band Square Fractal Microstrip Antenna for Sustainable Development in Wireless Communication

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Abstract

A multiband square contoured self affine fractal microstrip antenna is proposed for sustainable greener development. The designed antennas are optimized using IE3D antenna design simulation tool. The 1st and 2nd iterations of the design are minutely compared in terms of Voltage standing wave ratio, Return Loss, Resonant Frequency and Gain. The designs show multiband frequency characteristics ranging between 1.82 GHz to 8.80 GHz. In this work utmost 2 iterations have been incorporated on square patch antenna. The size reduction of 34.84% for first iteration and 59.02% for next iteration is accomplished for the microstrip antenna 2 and 3 respectively.The geometry of the designed antennas are fabricated on FR4 material having substrate height of =1.6 mm and ε_r= 4.4 dielectric constant of the substrate. The antenna parameters are tested using vector network analyzer (800 MHz to 40 GHz) with S820E model and in Anechoic Chamber. Measured results agree with simulated data.The anticipated antenna finds applications in ISM, C band and Wi-Fi frequency applications where antennas can employed for RADAR and satellite communication purposes.

Key words: Multi Band Antennas, Resonant Frequency, Space-Filling, Microstrip Patch Antenna, VSWR.

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1 .Introduction

In the present competitive changing global market forecasts a tremendous ever-growing demand for compact multiband microstrip antenna designs and fabrications for consumer and defense applications, a remarkable importance is being placed on saving energy. Conventional antennas generally operate at a single frequency band, where as dual/multiband antennas are needed for wireless communications requiring multiple applications. Hence there exists the need of requirement of large space for different antennas and more energy. In order to surmount this drawback, compact sized microstrip antenna [1] and having multi frequency can be employed where a only one antenna can operate at many different frequency bands with small size and achieving energy efficient by reducing number of antenna required. Application of fractal geometry to microstrip antennas are more popularly utilized because of their various benefits and merits such as compact in. size, low-profile, light in weight , occupation of less space, conformal, compatibility with microwave integrated circuits, cost effective and easy to install on the rigid surface. This has started initiation in the antenna research in various directions, one of which is by using fractal geometry for the design of antenna elements. The recent literature study shows so many fractal antenna geometries have been presented for microstrip antenna applications with adaptable degrees of achievement in getting better antenna characteristics. In 1951, Mandelbort proposed the fractal geometries [2]. A self-similar fractal geometry is one that composed of scaled down versions of its own, i.e., a reduction which downsizes shape by the same quantity in vertical and horizontal directions. But in self-affine fractal geometry is contraction is carried out such that the picture down sizes by a different factors along horizontal and vertical directions. Thus, it can give extra flexibility in the design of microstrip patch antenna, since by choosing the scale factors properly; resonance frequencies can be spaced by diverse factors.

In recent years a number of antenna designs which function on fractal geometries have been reported. The fractal geometry that guarantees the successful design of a multiband or reduced size antenna is basically called as the Sierpinski gasket. The Sierpinski gasket fractal geometry patch antenna has multi-resonant behaviors and is described in [3], [4]. Further by utilizing fractal geometry to the microstrip antenna overall size has been reduced and gain and bandwidth gets increased in I shaped fractal antenna A coaxial feed is employed for impedance match up. Total 3 iterations are used and the number of bands increases from one to four. Return loss S11 of -22.13db reached along with excellent VSWR [5,6]. In another work, space saving of more than 33.8% % and obtained multiband frequency of operation over the range 1GHz to 4GHz The maximum frequency bandwidth obtained is 70MHz in 1st iteration but gain parameter is not studied [7,8].

Results and discussion are described in Section 3. Experimental validation is also explained there. At the end, conclusions of the research work are drawn in Section 4.

2 Design of Antenna

2.1 Basic Geometry (Antenna 1, 0th iteration)

The basic geometry used is a square microstrip antenna with probe feed and its dimensions decide the resonant frequency (f_r). The square microstrip geometry used has the dimensions of 29mm^2 and its dimensions are designed using the equations (1) to (5)

$$W = \left(\frac{c}{2fr}\right)\left(\sqrt{\frac{2}{\epsilon r+1}}\right) \quad (1)$$

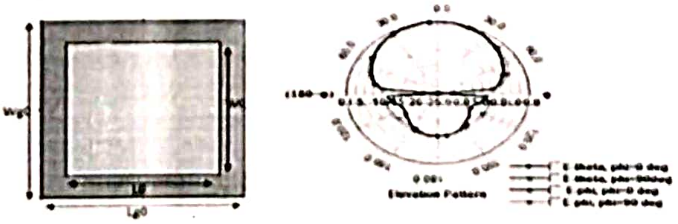
$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{1 + 12h/w} \quad (2)$$

$$L = \frac{c}{2fr\sqrt{\epsilon reff}} \quad (3)$$

$$\Delta L = L - 2\Delta L \quad (4)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)} \quad (5)$$

Where ε_r = Substrate dielectric constant of, ε_{reff} = Effective substrate dielectric h = Substrate Height, ΔL= Extension of patch length, W = Width of the patch and L=Length of the antenna. All geometries presented in this work (antennas 1, 2 and 3) are designed by using equations on low priced FR-4 dielectric substrate with ε_r = 4.4 having substrate thickness t= 1.6 mm, and the loss tangent δ = 0.02. Figure 1(a) illustrates the geometry proposed patch antenna-1.The optimization was performed using IE3D with number of iterations for the best impedance bandwidth, gain and for multiband operation. The overall Ground size (Lg_0*Wg_0) used is 39mm x 39mm. The simulated radiation plot obtained at 2.4GHz frequency is revealed in figure 1(b) and it shows omni-diectional characteristics.Good antenna efficiency 33.7% and antenna radiation efficiency 42.84% is attained at 2.4GHz with 6 dBi directivity.



a) Basic patch geometry of antenna b) 2D Radiation pattern
Figure 1: Basic geometry of antenna1and its radiation patterns at 2,4GHz

The work of incorporation of fractal geometry affect decrease in volume and less cost effective antenna features in I shaped antenna which demonstrated peak bandwidth and admirable impedance match up at 5.88 GHz, 6.70 GHz, and 7.23 GHz resonanance frequencies[8,9]. Further by the use hexagonal figured multiband patch antenna presented covers 1-6 GHz frequency]. The 1.8GHz band resulted bandwidth of 345MHz, return loss -22.3dB and other at 3.7GHz resulted bandwidth of 500MHz and return loss -15dB [10,11]. A circular shaped frcatl patch also studiedby introducing tringels has been proposed [12,13] which attained multibands and finds use of frequencies in C,Ku and X bands. There are several works available in literature as listed in table1 which focuses on rectangular fractal patch with self-similarity. However, this work focuses on square patch geometry with self-affine property of the fractal of novel shape for multiband function and size reduction [14,15]. The performance parameters of antenna such as Bandwidth, radiation plots, voltage standing wave ratio, return loss, and number of resonance frequencies, etc have been investigated thoroughly[16].

Table 1: various techniques used in the literature

Sl. No	Technique	Input Parameter	Output parameter
1	I Shaped Fractal Antenna [5]	Substrate RT duroid-5880(εr =2.2) Size 37.6218 mm² thickness of 2.6 mm	Multiband at 4.7 GHz, 6.5 GHz, 7.7 GHz Uses in C and X band
2	Plus Shaped Fractal Antenna[6]	Substrate FR4 (εr =4.4) size 30 x 40 mm² h=1 6mm Probe feed	Size reduction of 33.8%. Multiband ranges 1GHz to 4GHz.
`3	I-Structured Fractal Antenna [7]	Substrate FR4 (εr =4.4) Size 30.2 x 20 mm² thickness =1.57 mm Tan δ=0.019.	Size reduction by 12.47% multiband at 5.88, 6.70, and 7.23 GHz. emergency management and C band
4	Hexagonal Shaped Fractal Antenna[8]	Substrate FR4 (εr =4.8) size 60 x 80 mm² h=1.59 mm, Tanδ =0.019	Multiband covers 1-6Ghz finds uses in WLAN/WIMAX applications.
5	Circular patch with isosceles triangles[9]	Substrate FR4 (εr =4.4) Patch Size 60×55 mm² thickness of h=1.59mm.	Multiband operation Wimax, WLANV2X And RADAR uses
6	Proposed novel square shaped Fractal Antenna Size 29mmx29mm for multiband and size conpactness with peak gain		

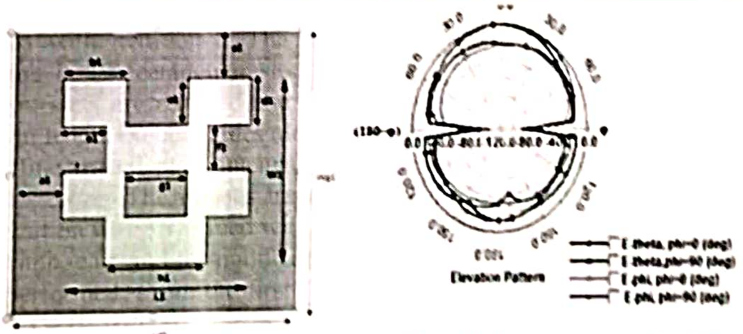
The design and optimization is performed using IE3D antenna design simulation tool [17-19]. Experimental realization is carried out to validate the simulated results. Section 2 focuses on basic antenna design and its operation. It is also shown that how self affine fractal geometry can be derived from conventional square geometry.

2.2 Antenna 2, with Iteration-1

Figure 2(a) demonstrates the configuration of the proposed square antenna with iteration-1. The structure 29mm x29mm is reduced to 1/3 resulting in 12 rectangular slots of size 9.66mm x7.25mm. Among twelve only six slots are retained and out of which middle 2 center slots are fine tuned in length on both sides along x axis direction by 9.66/3=3.22mm to get self affine fractal path antenna. The ground size ($Lg_1 x Wg_1$) is maintained 39mm x 39mm.The various fractal dimensions are tabulated in Table 2.The optimization was performed with number of iterations for the best impedance bandwidth, gain and for multiband function and practical measurements have been performed. From the first iteration it may be noted that a total size of antenna was reduced by 34.84%. The figure 2(b) shows simulated 2D Radiation Pattern at 6.74GHz and depicts that antenna 2 has radiation plot of omni-directional shape and good gain together with multiband operation. Good antenna efficiency 37.96% and antenna radiation efficiency 43.01% is attained at 7.25GHz with directivity 10.01dBi.

Table 2: List of dimensions of antenna geometry 2

Element	a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1
Dimension(mm)	5.0	9.66	7.25	7.25	6.44	7.25	9.66	16.1



(a) Antenna 2 Geometry (b) Radiation patterns at 6.74GHz

Figure 2: Antenna 2 geometry and its radiation patterns.

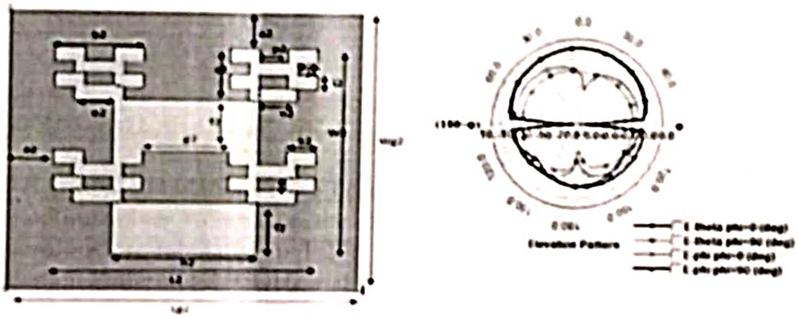
2.3 Antenna 3, with Iteration-2

Figure 3(a) shows the configuration of iteration 2 for antenna 3. The slots with size of 9.66mm x 3.22 mm are reduced to 1/3 which resulting in 24 rectangular slots (shapes) of size 3.22mm x 2.41mm. By retaining only 6 rectangles out of which 2 center rectangles are varied in length in both direction of x-axis by an amount 3.22/3=1.07mm to obtain self affine fractal path antenna. The overall Ground size ($Lg_2 x Wg_2$) used is 39mm x 39mm. From the second iteration it may be illustrious that a total size of antenna was reduced by 59.02%.

Repeated simulations have been performed at various feeding points to get optimization values for the designed geometry.The different fractal dimensions are tabulated in Table 3. The Figure 3(b) shows simulated 2D Radiation Pattern at 2.95GHz and depicts that antenna 3 has omnidirectional pattern and peak gain. Good antenna efficiency 39.06.7% and antenna radiation efficiency 39.07. % is attained at 8.65 GHz with 9.7dBi directivity.

Table 3: List of various parameters of antenna geometry 3

Element	b_2	c_2	d_2	e_2	f_2	g_2	h_2	i_2	j_2	k_2
Dimensions (mm)	9.66	7.25	7.25	6.44	7.25	9.66	16.1	9.66	9.66	16.1

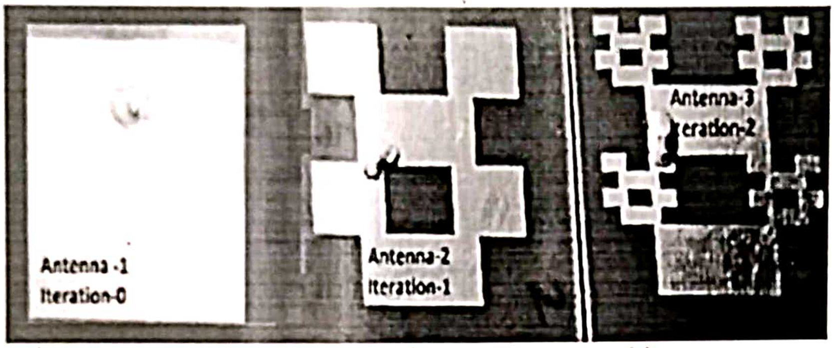


(a) Antenna 3 Geometry (b) Radiation patterns at 2.95GHz

Figure 3: Antenna 3 geometry and its radiation patterns.

3 Results and Discussion

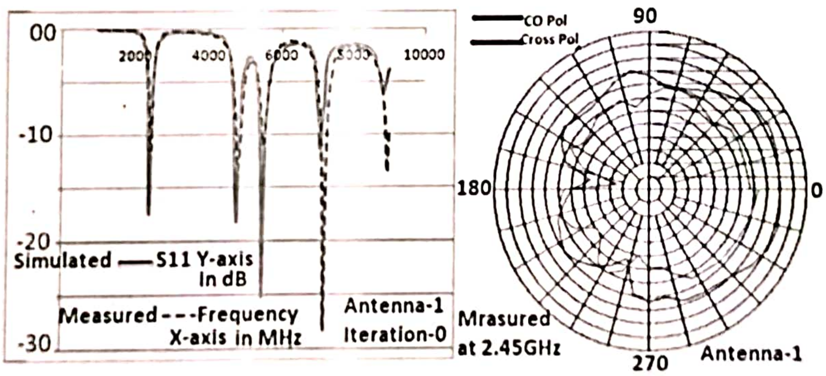
All geometries demonstrated in Section 2 have been fabricated and tested and are shown in diagram 4. Antennas have been tested with Vector Network Analyzer (Microwave Site Master S820E). The simulated and practical results obtained are tabulated in Table4. Figure 5(a) shows the comparative analysis of return loss S_{11} for the basic patch antenna. From the plots it may be noted that return loss values of both simulated and practical values agreed each other. The radiation plots have been tested and calculated in an anechoic hall and are presented in Figure 5(b). Measured patterns fairly agree with simulated ones and it may be noted that cross polarization values are less than -20dB.



(a) (b) (c)

Figure 4: Fabricated antennas (a) Basic geometry (b) Antenna 2-iteration 1 and (c) Antenna 3-iteration 2.

The patterns presented also indicate the omni-directional behavior for all the cases considered. The simulated and measured antenna gain is 2.12dB and 2.13dB at 2.4GHz and gain of 4.28dB & 4.65dB at 7.08 and 7.18GHz GHz respectively. The basic patch antenna operates at multiband having good return loss at resonant frequencies 2.4 GHz, 4.75GHz, 5.50GHz and 7.08GHz. A maximum measured bandwidth of 107 MHz at 7.18GHz is achieved.



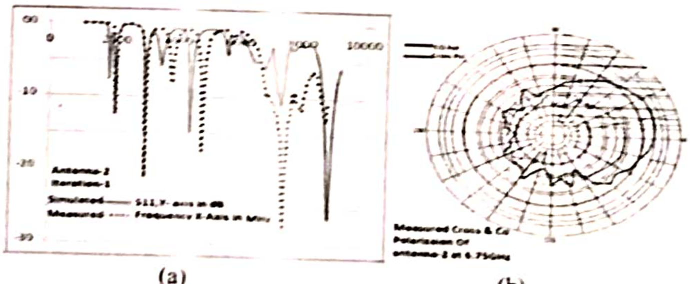
(a) (b)

Figure 5: Input characteristics of Antenna 1geometry (a) Return loss vs. frequency (b) Radiation plot

Table 4: Comparison table of different iterations

Antenna Types	Resonant Frequency (GHz)		Return Loss (S_{11}) (dB)		Gain (dB)		VSWR	
	Simulated	Measured	Simulated	Measured	Simulated	Measured	Simulated	Measured
Antenna-1 Iteration-0	2.40	2.40	-17.36	-11.38	2.12	2.13	1.31	1.26
	4.76	4.73	-18.08	-13.40	1.17	-9.10	1.29	1.54
	5.46	5.50	-25.12	-10.99	-0.02	-16.0	1.13	1.77
	7.08	7.18	-11.33	-28.42	4.28	4.65	1.84	1.06
Antenna-2 Iteration-1	2.01	2.01	-13.08	-12.49	-6.22	-20.0	1.96	1.64
	2.93	2.97	-15.76	-21.05	0.15	-22.0	1.85	1.19
	4.70	4.78	-13.62	-17.28	1.48	-1.50	1.73	1.32
	6.75	7.40	-11.08	-26.96	3.60	5.40	1.73	1.10
Antenna-3 Iteration-2	1.78	1.82	-11.95	-10.62	-6.12	-17.0	1.70	1.87
	1.99	1.99	-12.63	-13.12	-9.23	-10.0	1.60	1.68
	2.91	2.93	-14.26	-24.10	0.23	2.19	1.57	1.25
	4.32	4.40	-22.47	-15.62	-3.24	-2.02	1.18	1.12
	8.67	8.80	-29.03	-22.7	5.46	2.1	12	1.31

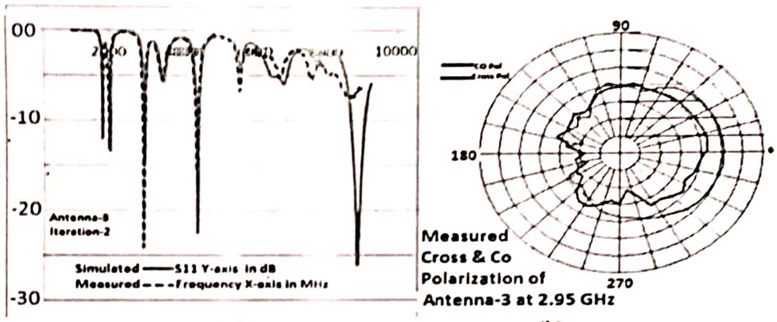
The antenna 2 with iteration1 (square microstrip antenna with application of fractal geometry) operates at 4 multiband frequencies, 2.01GHz, 2.97 GHz, 4.78 GHz and7.40GHz respectively. As shown in diagram 6(a), the simulated and measured values shows that having good return loss & vswr and a gain of 3.60dB for simulation and practically measured gain of 5.4dB is obtained at around 7GHz resonant frequency. Diagram 6(a) demonstrates the return loss comparative analysis of S11 for the antenna-2. The antenna radiation plot demonstrates omnidirectional characteristic at 6.75 GHz and cross polarizations are less than 20dB as revealed in Figure 6(b).



(a) (b)

Figure 6: Input characteristics of Antenna 2 geometry (a) Return loss vs. frequency (b) Radiation plot

The antenna 3 (square microstrip antenna with iteration-2) also operated at multiband frequencies having measured good return loss of -11.0236 dB , -20.8174 dB & -29.3724 dB at resonant frequencies 1.82GHz, 1.99GHz, 2.95GHz and 4.40 GHz respectively, with maximum BW of 46 MH at, 2.95GHz and gain of 2.19 dB obtained which are well suited for ISM, Wi-Fi and C band applications. Figure 7(a) shows the return loss comparative analysis of S_{11} for the antenna-3. The antenna 2D radiation pattern is presented in Figure 7(b) indicates stable radiation characteristic at 2.95 GHz



(a) (b)

Figure 7: Input characteristics of Antenna 3geometry (a) Return loss vs. frequency (b) Radiation plot

4 Conclusion

Squqre micro strip fractal antenna is presented where maximum 5 multi bands were obtained with peak gain of 5.4dB which indicates energy saving in comparison with single antenna and size shrinkage of 59.02% is being attained. The operating frequencies obtained with optimum results are 2.4GHz with the BW of 256MHz, 7.40GHz with BW of 640.96MHz and 2.95GHz with BW 46MHz. These frequencies are useful for applications where multiband function with a larger frequency bandwidth is essential and for compact size i.e., in S band (unlicensed applications) like Wi-Fi, ISM, LTE, and Blue tooth modules (Long distance radio telecommunications, Satellite, Microwave relay) and with these findings the proposed geometry is good candidate for WIMAX and C band frequency applications. Firther work may be carried out by change in feeding location, different feeding types and use of EBG structures may be attempted to obtain good gain with optimizations techniques.

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References

[1]J. R. James and P. S. Hall, "Handbook of Microstrip Antennas", Peter Peregrines Ltd., 1989.

[2]S. Sureshkumar, P. M. R. Anand, A. Prajapati and K. S. Sankaran, "Negative Index Metamaterial Based Dual-Band Microwave Absorber," 2018 International Conference on Communication and Signal Processing (ICCSP), pp. 897-900, 2018

[3]D. H. Werner and S. Ganguly, "An overview of fractal antenna engineering research," IEEE Antennas and Propagation Magazine., vol. 45, no. 1, pp.38–57, 2003.

[4]Sachendra N. Sinha and Manis Jain "Self-Affine fractal multiband antenna" IEEE Antennas and Wireless letters, vol. 6, pp. 110-112, 2007.

[5]S. Kohli, S.S. Dhillon, and A. Marwaha, "Design and optimization of multiband fractal microstrip patch antenna for wireless applications", IEEE International Conference on Computational Intelligence and Communication Networks, pp. 32-36, 2013.

[6]S. Jagadeesha,R. M. Vani, P. V. Hunagund "Size reduction and multiband operation of rhombus shaped fractal microstrip antenna for wireless applications" International Journal of Electronics and Communication Engineering & Technology, vol. 3, no.2, pp. 445-450, 2012.

[7]Sushil Kakkar, T. S. Kamal & A. P. Singh, On the Design and Analysis of I-Shaped Fractal Antenna for Emergency Management, IETE Journal of Research, Vol. 65, no.1,pp.104-113 , 2019

[8]Amanpreet Kaur, Nitin Saluja, J S Ubai ,A Hexagonal multiband fractal antenna using for wireless applications, International Journal of Electronics and Computer Science Engineering, Vol. 4,pp.2107-2111,2007.

[9]S. Chatterjee, S. S. Kumar, A. N. Raut, K. Sakthidasan Sankaran and P. M. Rubesh Anand, "A Wide Band Balun Design using Metamaterial Technique for Low Frequency Antenna Application," 2019 International Conference on Communication and Signal Processing (ICCSP),pp. 0735-0738, 2019

[10]K.Thenkumari & K.Sakthidasan @ Sankaran, "Frequency reconfigurable micro strip antenna switching techniques for sustainable environment", Journal of Green Engineering, Volume 9, no.4, pp. 502-513, 2019

[11]I. S. Bangi and J.S.Sivia "Minkowski and Hilbert curves based hybrid fractal antenna for wireless applications", International Journal of Electronics and Communications (AEU), Vol. 85, pp. 159-168, 2018.

[12]A.Ismahayati, P. J Soh, R.Hadibah, G.A.E Vandenbosch "Design and analysis of a multiband Koch fractal monopole antenna", Proceedings of IEEE International RF and Microwave Conference, pp. 58-62, 2011.

[13]A. Dalmiya and O. P. Sharma "A novel design of multiband Minkowski fractal patch antenna with square patch element for X and Ku band applications" International Conference on Recent Advances and Innovations in Engineering (ICRAIE), pp. 1-6, 2016.
[14]P. Tang and Parveen Wahid, "Hexagonal fractal multiband antenna," Antennas and Propagation Society International Symposium, pp. 554-557, 2002.
[15]J. Pourahmadazar, C. Ghobadi, Javad Nourinia, and H. Shirzad "Multiband ring fractal monopole antenna for mobile devices "IEEE Antennas and Wireless Propagation Letters, vol. 9, pp. 863 – 866, 2010
[16]Suresh Akkole and N. Vasudevan," Square microstrip Multiband fractal Antenna Using EBG Structure for Wireless Applications", International Journal of Pervasive Computing and Communications,pp.1742-7371, 2019
[17]S. Sureshkumar, P. M. Rubesh Anand, A. Prajapati and K. S. Sankaran, "Low Pass Filter Design with CSRR as Defected Ground Structure," 2018 International Conference on Communication and Signal Processing (ICCSP), pp. 893-896, 2018.
[18]Kostas Tsagkaris et al., "Introducing Energy Awareness in the Cognitive Management of Future Networks" Journal of Green Engineering,vol.1,no.4,pp.383-412,2011
[19]Jain, A. and Modani, D. U. S."A literature Review of Multi-Frequency Microstrip Patch Antenna Designing Techniques', International Journal of Research in Engineering, IT and Social Sciences,Vol.7, no.6, pp.441-455,2017.

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