ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PENTAGONAL SHAPED KOCH FRACTAL MONOPOLE SLOT ANTENNA FOR MULTIBAND APPLICATIONS

D. S. Ramkiran, B. T. P. Madhav, B. Lakshmi Anusha, T. Lakshmi Bhargavi, L. Vardhan Reddy, P. Yashwanth and T. Anilkumar

Department of Electronics and Communication Engineering, K L University, Vaddeswaram, AP, India

E-Mail: btpmadhav@kluniversity.in

ABSTRACT

In this paper, a compact monopole multiband antenna is presented. A microstrip line fed pentagon shaped monopole element is served as radiating patch in this antenna. The slots are made in the patch in Pentagonal-Gasket-Koch (PGK) structure. The performance of antenna with different fractal iterations is studied. The base antenna structure results multiple resonating modes, where as the consecutive antenna iterations are contributing a multiple wideband response. The proposed radiating structure exhibits the multiple wideband 1.432-3.064 GHz, 5.02-7.189 GHz, 9.302-15.579 GHz, 16.831-20 GHz. The PGK fractal slot iterative structures incorporated in pentagon monopole antenna is studied in terms of other parameters such as peak gain, radiation performance and proves to be useful in various multiband applications such as DCS, LTE 2600, WLAN and radiolocation, mobile applications.

Keywords: fractal antenna, pentagonal-gasket-koch (PGK) structure, multi-wideband.

1. INTRODUCTION

The increasing popularity in wireless communication systems is catalysing the demand for innovative antenna designs with highly desirable attributes such as low-profile, compact size, multi-band, wide operating bands etc. Varieties of approaches have been developed over several years to address these objectives. The term fractal geometries refer to a family of complex shapes having self-similar/self-affinity property was first demonstrated by Mandelbrot [1]. Their self-similar structure can make them to operate the antenna in a similar manner even at different wavelengths; moreover, their space filling property of these antennas makes use of small space around it [2].

In the past literature, the fractal concept has been experimented in several ways in antenna design with various perspectives and some of them are presented here. A planar antenna geometry with perturbed Sierpinski fractal shape is proposed in [3] for obtaining a dual-band LTE applications. A Spidron fractal DRA is presented in [4] to generate a circularly polarized radiation. In [5], a CPW fed multiband slot antenna using fractal geometry is proposed and obtained the bidirectional radiation pattern and operate at DCS, WiMAX, IMT, WLAN applications. A log-periodic square fractal antenna is demonstrated in [6] which provide a miniaturization up to 23%. A MIMO mobile terminal antenna with Koch pre-fractal edge and a slot in U-shape is proposed in [7] for multi-standard applications such as GSM 1800, UMTS and HiperLAN2. A combination of two dual Koch fractal structures which formed a novel geometry known as dual-reverse-arrow fractal (DRAF) antenna which is implemented on equilateral-triangular patch is introduced in [8] and achieved a 40% size reduction when compared to similar triangular antenna. In [9], a monopole antenna with Koch fractal configuration is demonstrated to achieve the multiband behaviour. An Appollian-like gasket fractal antenna is presented in [10-12] with CPW-feed exhibits the multiband behaviour at 1.26 GHz, 4.66 GHz, 7.8 GHz for short range wireless applications and a tri-band Koch pentagonal fractal antenna with reduced size is reported in [13-16] for S, C and X band applications. In the present research, the antenna design is proposed to obtain the multiple wideband operating characteristics with good radiation properties.

In this paper, the basic pentagon monopole antenna is designed with a partial DGS ground. The design iterations with PGK-fractal slots are demonstrated in Section 2. Section 3 discusses the simulation results of the design iterations and concluded in Section 4.

2. ANTENNA DESIGN

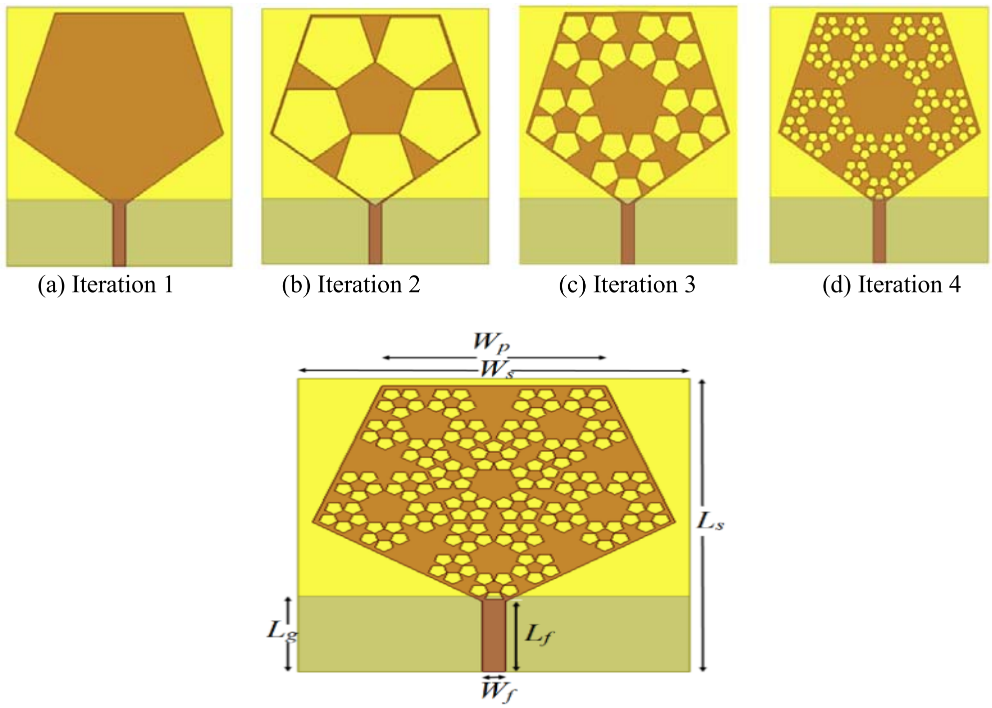
The design of a Penta-Gasket-Koch structured Fractal slot antenna is made on Rogers RO4003 substrate with thickness 1.5mm and relative permittivity of 3.55 having magnitudes of width, length as 60mm x 70mm. The antenna design concept is extracted from [12].The partial ground plane of length 18mm is etched on the bottom side of the substrate and the top side a layered with a regular pentagon shape patch of radius 29.18 mm and edge length of 34.3 mm. A micro strip feed of 50ohm characteristic impedance is connected to the patch to provide excitation signal through an SMA connector and the feed line is having width of 3.5 mm .In the iteration1, shown in Figure-1, the pentagon patch is fractalized with a PGK slot structure. The elements in the PGK structure is a pentagon with a scale factor of 37.3% and are placed and slotted the copper portion at the corners patch. The scale factor (*SF*) is computed based on the following expression in which $r_{n-1}$is radius of the pentagon slot in $(n-1)^{th}$ iteration and r_n is radius of the pentagon slot of n^{th} iteration.

$$r_{n-1} = 2.68 \times r_n \quad (1)$$

ARPN Journal of Engineering and Applied Sciences

$$SF = \frac{r_n}{r_{n-1}} \times 100 \quad (2)$$

This self-similar structure is iteratively modelled as slots for the proposed antenna and in the proposed model is incorporated with additional PGK slots at the center.



(a) Iteration 1 (b) Iteration 2 (c) Iteration 3 (d) Iteration 4

(e) Iteration 5

Figure-1. Geometrical evolution of the proposed PGK fractal slot antenna.

Table-1. Dimensions of the proposed antenna.

Parameter	L_f	L_g	L_s	W_s	W_f	W_p	h
Dimension in mm	16.8	18	70	60	3.5	34.3	1.5

3. RESULTS AND DISCUSSIONS

The proposed designs simulated in High Frequency Structure Simulator in ANSYS Electronic Desktop package 17. The return loss characteristics of the antenna are shown in Figure-2. It can be observed that the antenna iterations from 1 to 4 possess multiple resonant modes in the band ranging from 1-10 GHz. The antenna with slotted at the centre portion of pentagon patch forms the Iteration 5 merges the multiple resonant modes and provides the enhancement of bandwidth. The calculation of bandwidth is considered according to the -10 dB impedance bandwidth criteria. Finally, the Model 5 exhibits the multi-wideband characteristics.

VOL. 12, NO. 15, AUGUST 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

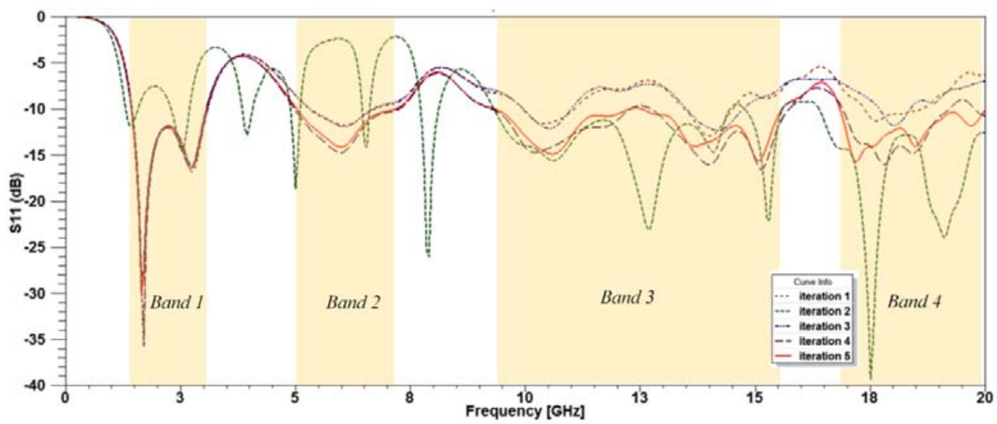


Figure-2. Return loss characteristics of the PGK fractal slot antenna iterations.

The return loss of -29.9182 is obtained at 1.6GHz of frequency for the proposed antenna where three bands are produced which indicates the antenna works at multiband frequencies.

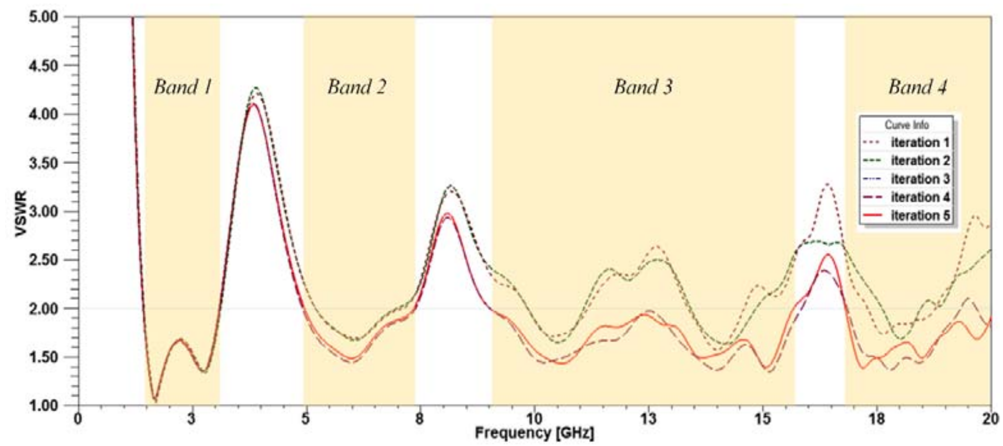


Figure-3. VSWR characteristics of the PGK fractal slot antenna iterations.

The standing wave ratio patterns are shown in Figure-3 with necessary operating band designations which are considered according the VSWR value less than 2 as an operational band. The initial models comprising of multiple bands with some narrow ranges, whereas the 4th and 5th iterations are achieving the multi-wide operating bands. The minimum VSWR is obtained at 1.65 GHz as 1.0659.

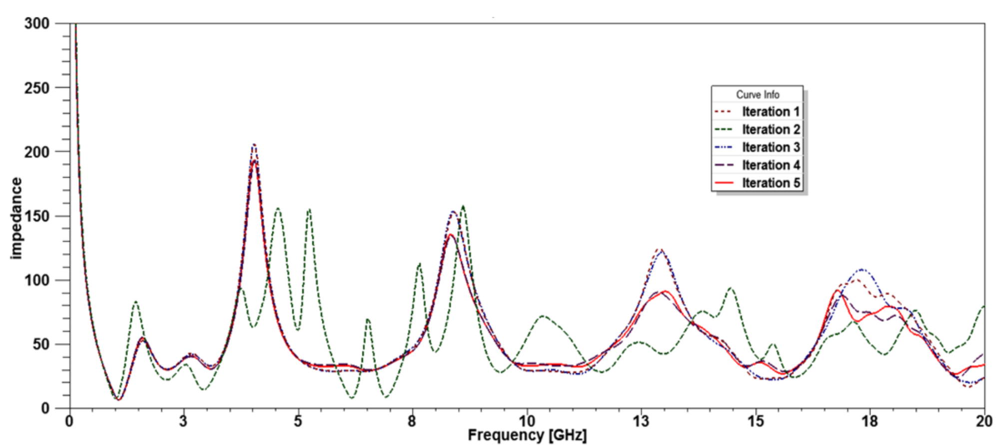


Figure-4. Magnitude of input impedance characteristics of the PGK fractal slot antenna iterations.

VOL. 12, NO. 15, AUGUST 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

The input impedance vs. frequency characteristics are shown in Figure-4. The magnitude of input impedance is maintaining range 40~50ohms and having a consistent impedance at the operating bands of each antenna iterations. This magnitude raises to a value nearly 200ohms indicating the existence of the band rejection.

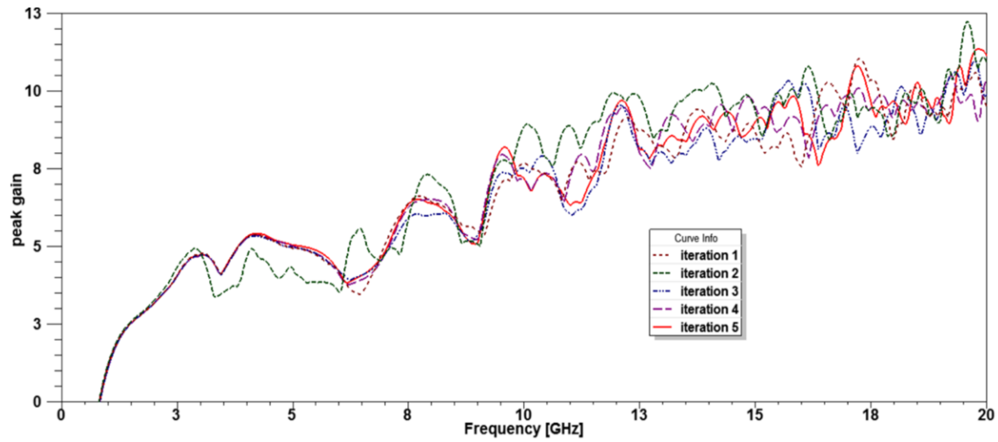
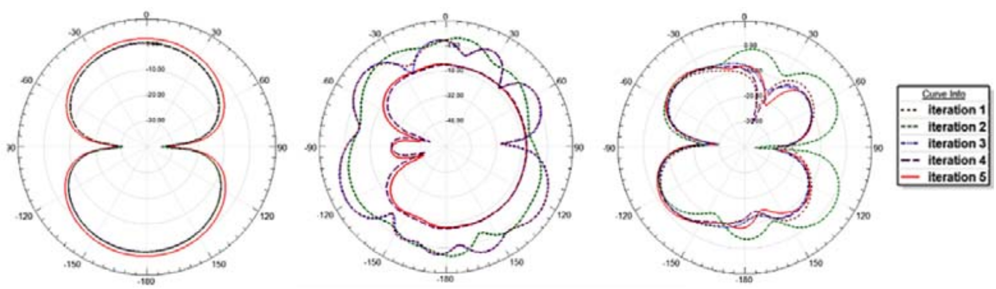


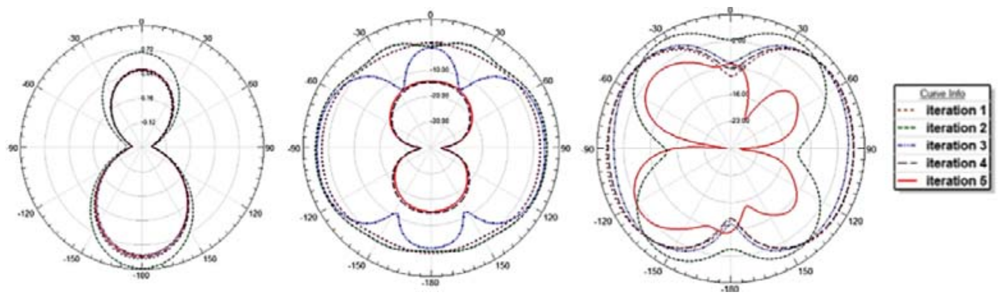
Figure-5. Peak gain Vs Frequency characteristics of the PGK fractal slot antenna iterations.

In Figure-5, the peak gain vs frequency characteristics of the PGK fractal slot antenna iterations is computed and plotted. The gain is observed more than 3 dB at any instance. The rise and fall nature of the curve is observed and which indicates efficient radiation in the operating band and shows decreased radiation performance in rejected bands.



(a) at 1.6 GHz (b) at 6 GHz (c) at 10 GHz

Figure-6. 2D (E-plane) radiation patterns of all antenna iterations.



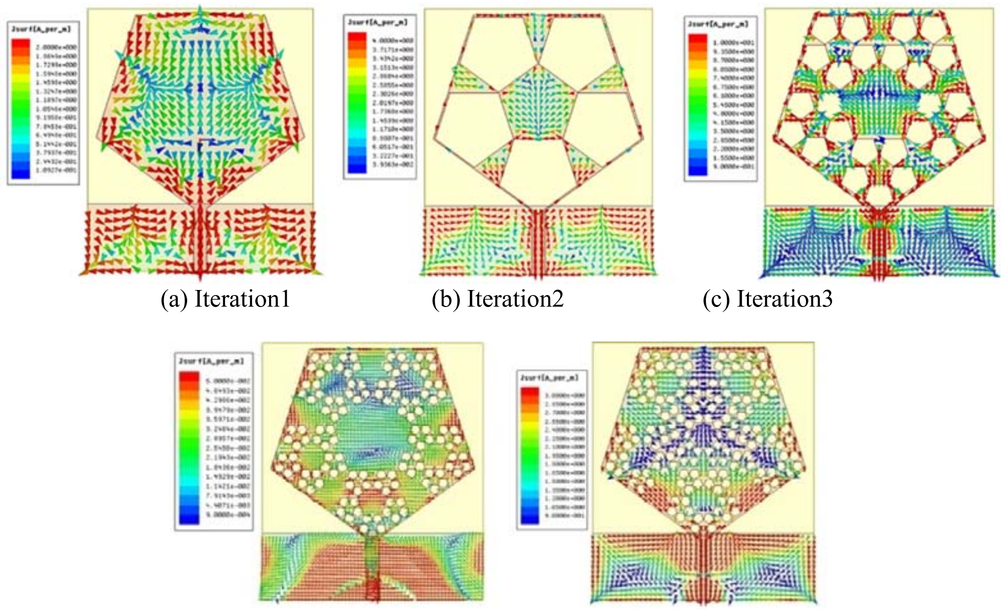
(a) at 1.6 GHz (b) at 6 GHz (c) at 10 GHz

Figure-7. 2D (H-plane) radiation patterns of all antenna iterations.

Radiation characteristics of the fractal slot antenna iteration are plotted in Figure-6 and Figure-7 shows the E-plane and H-plane radiation properties respectively. Each plot is characterized at three frequencies to understand the radiation behaviour over the operating bands. At low frequency, such as 1.6 GHz E-plane patterns follows a dumbbell shaped radiation characteristics showing a bidirectional radiation of the antenna. Due to the partial ground and the slotted configuration of the radiating element the back radiation is more. At 6GHz mid frequency the patterns of H-plane are nearly Omni directional in E-plane and the nulls are

VOL. 12, NO. 15, AUGUST 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

observing towards the feed line part of the antenna in E-plane patterns. At 10 GHz the dumbbell shaped pattern is getting deformation including nulls along the axial direction of the feed line and thus producing the nearly quad beam pattern in H-plane for iteration 4, 5 in H-plane.



(a) Iteration1 (b) Iteration2 (c) Iteration3

(d) Iteration4 (e) Iteration5

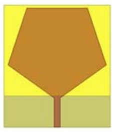
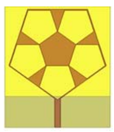
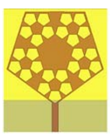
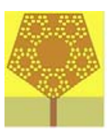
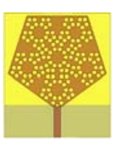
Figure-8. Distribution of surface current elements on all antenna iterations at 10 GHz frequency.

The variation of distribution of the current elements on the surface of the radiating element and the ground plane is shown in Figure-8. The current elements are found to be converging at the corners of the pentagon patch elements and a phase reversal is obtained at the lines that bisect the edges of the pentagon which can be shown in Iteration 1. In Iteration 2, the portions at the corners are slotted in a pentagon shape leaving the copper portion over edge centres that joins the patch centre. Now the narrow path along the edges of the pentagon patch exists for the current elements to contribute the resonances. This pattern exists even in all slotted iterations which show the self-similar nature of the fractal slots. In all iterations, the current elements are following the symmetrical pattern on each half of the ground plane that exists at either side of the feed line and at the centre portion has minimum current density. In Iteration5, the minimum current density exists as tri-axial pattern which is having centre coincides with the centre of the radiating element due to the further etching of PGK slots in the centre portion of the radiating patch.

VOL. 12, NO. 15, AUGUST 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-2. Consolidated parameters of PGK fractal slot antenna iterations.

Antenna geometry	Operating band (GHz)	Resonant frequency	Gain (dB) over the operating band		Fractional bandwidth (%)
			Maximum	Average	
 1	1.444-3.083	1.700	4.778	3.657	96.38
	5.298-6.741	6.007	4.870	4.147	24.01
	9.934-11.057	10.398	7.666	7.248	10.79
	13.448-14.510	13.995	9.414	8.951	7.59
	17.358-18.632	17.601	10.617	9.570	7.23
 2	1.306-1.575	1.400	2.606	2.455	19.21
	2.293-2.695	2.255	4.426	4.030	15.76
	3.838-4.067	3.900	5.337	5.220	5.81
	4.887-5.102	5.000	4.990	4.953	4.30
	6.449-6.614	6.550	3.770	3.588	2.50
	7.716-8.111	7.900	6.613	6.502	5.00
	9.308-14.445	12.700	9.414	7.992	40.40
	14.755-15.587	15.300	8.956	8.386	5.43
 3	1.445-3.090	1.700	4.735	3.643	96.78
	5.309-6.698	6.050	4.862	4.315	22.97
	9.941-10.995	10.500	7.906	7.343	10.03
	13.489-14.737	14.200	8.799	8.343	8.78
	17.684-18.367	18.000	10.138	9.524	3.76
 4	1.431-3.060	1.650	4.729	3.630	98.74
	4.974-7.261	6.000	5.609	4.472	38.11
	9.247-15.741	15.150	9.816	8.377	42.86
	16.887-19.225	17.800	10.488	9.649	13.13
 5	1.432-3.064	1.650	4.744	3.647	98.92
	5.020-7.189	6.000	5.366	4.518	36.13
	9.302-15.579	10.600	9.693	8.206	59.21
	16.831-20	17.200	11.350	9.944	18.42

CONCLUSIONS

A pentagon shape monopole antenna with a partial defected ground structure is studied with the different iterative Penta-gasket Koch fractal slot geometries. The characteristic features such as the reflection loss and VSWR demonstrate that as the fractal iterations increased, the narrow operating bands are merged together to form a wideband nature of the antenna which provides the operating band characteristics at 1.432-3.064 GHz, 5.02-7.189 GHz, 9.302-15.579 GHz, 16.831-20 GHz. Moreover, the surface current distributions implemented with fifth iteration as radiating element. The designed antenna is proposed for multiband operations and can operate in L band, S band, C band, X band and Ku band spectra with DCS, LTE 2600, WLAN, radio location, vehicular and mobile applications. The radiation characteristics of antenna confirm the antenna as a good member for above mentioned applications.

ACKNOWLEDGEMENTS

The authors deeply express their gratitude to ARL-LC Research Centre, Department of ECE, K L University for their encouragement during this work. Further, Madhav would like to express his gratitude to DST through grant ECR/2016/000569 and FIST grant SR/FST/ETI-316/2012.

REFERENCES

[1] H. Orazi and H. Soleimanim. 2015. Miniaturisation of the triangular patch antenna by the novel dual-reverse-arrow fractal. in IET Microwaves, Antennas & Propagation. 9(7): 627-633, 5 15.

[2] Best, S. R. 2002. On the multiband behaviour of the Koch fractal monopole antenna. Microw. Opt. Technol. Lett. 35: 371-374.

[3] Kumar R. and Tiwari A. 2009. Design of Appollian-like gasket fractal antenna with coplanar waveguide (CPW)-fed. Microw. Opt. Technol. Lett. 51: 2836-2839.

[4] O. M. Khan, Z. U. Islam, I. Rashid, F. A. Bhatti, and Q. U. Islam. 2013. Novel miniaturized koch pentagonal fractal antenna for multiband wireless applications. Progress in Electromagnetics Research. 141: 693-710.

[5] Naghshvarian-Jahromi, Mahdi. 2008. Novel wideband planar fractal monopole antenna. IEEE Transactions on Antennas and Propagation. 56.12: 3844-3849.

[6] B. T. P. Madhav, M. Sai Charishma, P. Kavya, A. Sai Kumar and K. Supriya. 2017. Frequency Selective Surface Based Spiral Fractal Monopole Antenna, Far East Journal of Electronics and Communications, ISSN: 0973-7006, 17(1): 27-37.

[7] D S Ramkiran, P Siddaiah. 2017. Serrated circular fractal coplanar wave guide fed antennas for wideband and ultra wideband applications. IJCTA, ISSN: 0974-5572, 10(1): 259-266.

[8] K V L Bhavani, Habibulla Khan. 2016. Wideband CPW Fed Monopole Fractal Antenna with Defected Ground Structure. Journal of Engineering and Applied Sciences, ISSN: 1816-949X, 2016, 11(11): 2446-2454.

[9] M V Giridhar, T V Ramakrishna. 2016. Compact Fractal Monopole Antenna with Defected Ground Structure for Wide Band Applications. Journal of Theoretical and Applied Information Technology, ISSN: 1992-8645, 91(1): 23-27.

[10] D S Ram Kiran, B T P Madhav. 2015. Novel compact asymmetrical fractal aperture Notch band antenna. Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, 27(2): 1-12.

[11] K Phani Srinivas, B T P Madhav. 2015. Novel Koch fractal circularly polarized micro strip antenna for global positioning system application. Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, 27(2): 31-40.

[12] M. L. S. N. S. Lakshmi, B. T. P. Madhav. 2015. Analytical Study on Folded-Slot Koch Fractal Antenna. Indian Journal of Science and Technology, ISSN 0974-6846, 8(17): 66573-66578.

[13] B T P Madhav, K Sai ram, M Deepika, V Naresh. 2015. Circularly Polarized Koch Fractal Triband Antenna for Communication Applications. ARPN Journal of Engineering and Applied Sciences, ISSN: 1819-6608, 10(14): 5795-5801.

[14] S.S. Mohan Reddy, P. Mallikarjuna Rao. 2015. Partial Substrate Removal Techniques for the Enhancement of Gain and Radiation Characteristics in Fractal Antenna. Research Journal of Applied Sciences, Engineering and Technology, ISSN: 2040-7459, 10(1): 79-85.

[15] B T P Madhav, VGKM Pisipati, Habibulla Khan, D Ujwala. 2014. Fractal shaped Sierpinski on EBG structured ground plane. Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, (25): 26-35.

[16] B T P Madhav, Krishnam Naidu Yedla, G.S., Kumar, K.V.V., Rahul R. 2014. Fractal aperture EBG ground structured dual band planar slot antenna. International Journal of Applied Engineering Research, ISSN 0973-4562, 9(5): 515-524.