VERIFICATION OF MULTIBAND CHARACTERISTICS IN ITERATIVE FRACTAL ANTENNA

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ABSTRACT

This paper presents verification of multiband characteristics of a circularly shaped iterative fractal antenna with increasing number of fractal iterations. The four numbers of iterations are considered for this study. Also, the miniaturization characteristics of the fractal antenna with increasing number of fractal iterations have been studied. The proposed 4^{th} iterated fractal antenna is designed on FR4 substrate (h = 1.56 mm and ε_r = 4.3). The antenna is coaxially fed using surface mount adapter. The proposed circularly shaped fractal antenna is found to resonate at four centre frequencies such as 0.683 GHz, 0.97 GHz, 1.29 GHz, and 1.68 GHz. The antenna finds applications in various compact multiband wireless communications due its smaller size , low cross polarization and multiband behaviour.

KEYWORDS

Antenna, fractal, iterative, multiband, miniaturization.

1. INTRODUCTION

Multiband antennas have wide-spread its importance in wireless communication due to increasing demands for multichannel communication. Iterative multiband antennas are easy to design and capable of providing hardware lock by separation among the various bands. Advancement in wireless technologies enable various generations (1G, 2G, 3G, 4G, and 5G) of pocket based wireless communication those need compact antennas. Fractal patch antennas are capable of providing multiband characteristics as well as compactness. Fractal is known as fractus in Latin language to mean "broken" or "fractured" geometry. "A fractal is a rough or fragmented geometric shape that can be splitted into parts, each of which is (at least approximately) a reduced-size copy of the whole" [1]. Around 1975, B. Mandelbrot has reported existence of non-Euclidean geometries called as fractal and its use in many natural findings. A fractal is an integral part of nature and has applications in antennas for multiband wireless communication. The self similarity and space filling property in fractal can achieve multiband and miniaturization characteristics in antennas. Several fractal antennas have been reported for compact and multiband applications [1]-[16]. For faster wireless communication, bandwidth in multiband also needs to be appropriate to exploit the available data rate in various generations. Therefore, bandwidth enhancement becomes necessary, when bandwidth available in multiband antenna is narrow. There are many known methods reported in the literatures [5], [8]-[9] to enhance the antenna bandwidth those include design of the antenna with log-periodic profile, use of a low dielectric substrate, increase of the substrate thickness, use of travelling-wave topologies, use of efficient impedance matching and feeding techniques, use of multiple resonators and slot antenna geometry. The field pattern of an antenna and its control is second important parameter for effective wireless transmission and reception. The shape of the field

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pattern and its control can be easily designed using array techniques [7]. There are different types of arrays based on excitation amplitude level and phase, spacing between the array element and arrangement of array elements. These are uniform / non-uniform amplitude array, uniform / non-uniform spaced array, phase scanning array, end-fire array, broadside array, linear, circular, rectangular, random array etc based on the arrangement of the array elements. Arrays are also capable of gain enhancement. Fractal antenna can serve as an element of an array [7].

This work has verified the resonant behavior of the iterative fractal patch antenna reported in [5], [8] and [11] fabricated on FR4 substrate for multiband communication using simulation and measurement technique. Also, this work has shown the lower frequency shift in various iteration of fractal antenna compared to their conventional counterpart.

2. DESIGN OF ANTENNA

The proposed antenna design has been reported by Y. B. Thakare etal. in [5], [8] and [11] and is discussed below.

The design of the proposed antenna requires i. design of a conventional circular patch of 80 mm major axis dimension with major to minor axis ratio 0.98 (Fig. 1a) and ii. loading the conventional patch with a multi-triangular slot at 4^{th} iteration depth to design the fourth iterated proposed antenna. For loading multi-triangular slot, i. first generates four equilateral triangular slot of dimension 66 mm with its vertex at 0^0, 90^0 180^0 and 270^0 in the conventional patch in four steps as shown in Fig. 1b, 1c, 1d and 1e known as 1^{st} iteration fractal patch. ii. using this fractal patch and a scale down factor of 0.7125 generate 4^{th} iterated proposed fractal patch as shown in Fig.1h to design the proposed fractal antenna shown in Fig. 1i. Enough care must be taken to electrically connect inner boundary of larger patch with the outer boundary of smaller patch as shown in Fig. 1f. The design dimensions are given in Fig. 1i. The proposed antenna is fabricated using on FR4 (ε_r = 4.3, h=1.56 mm) substrate of area 110 mm x 110 mm backed by ground and probe fed at X= -24.85 mm and Y= 24.32 mm using 50 Ω connector as shown in Fig. 2. This feed point is optimized for minimum reflection loss. The photo of the fabricated antenna is shown in Fig. 3.

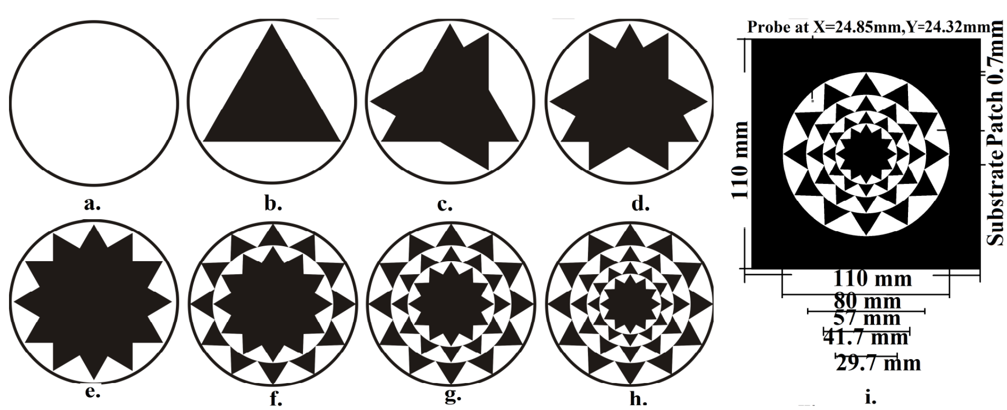

Figure 1. Design steps involved in the proposed antenna

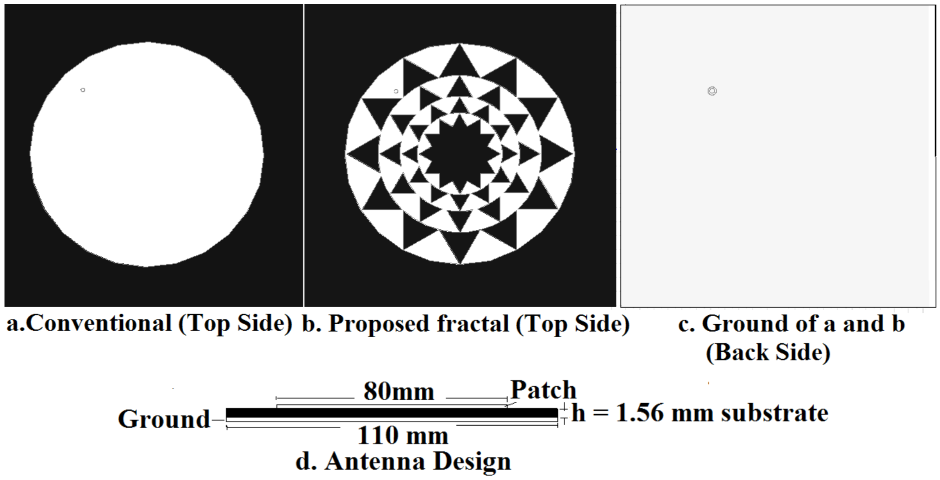

Figure 2. Design of the probe fed antenna [5], [8], [11].

Figure 3. Photo of the fabricated antenna [5], [15], [19].

3. RESULTS AND DISCUSSIONS

3.1 Reflection loss

The probe fed conventional and the designed fractal antennas in Fig. 2 are simulated using high frequency structured simulator based on finite element analysis method. The modelling of the antenna is done on FR4 substrate (ε_r = 4.3, h=1.56 mm) as per the design dimensions as discussed in section 2 using 3D modeller available in the simulator. The modelled antenna is excited using wave port with 50 Ω characteristics impedance. The simulated results are obtained by swiping the frequency between 1Hz to 3 GHz as shown in Fig. 4 and 5. The designed antennas fabricated on FR4 are tested using Agilent vector network analyzer 0-4 GHz as shown in Fig. 4. The simulation and measured return / reflection loss results for fourth iterated fractal antenna are compared in Fig. 4. The simulation results of fourth iterated fractal antenna are compared with conventional antennas of equivalent physical sizes as that of every fractal iteration and summarized in table1. The conventional patch (base) antenna resonates at a centre frequency of 1.04 GHz (measured) and matches closely with the simulation results as seen in table1. The simulated and the measured results for fourth iterated fractal antenna shown in Fig. 4 and table 1 are in close agreement with small differences due to fabrication tolerance. As shown in Fig. 5 and table 1, the proposed fourth iterated fractal antenna resonates at four distinct frequencies measured as 0.683 GHz (first iteration); 0.97 GHz (second iteration); 1.29 GHz (third iteration) and 1.68 GHz (fourth iteration). These frequencies correspond to four iterations of multi-triangular patches respectively. This is confirmed by simulating the probe fed antenna with four, three, two and single multi-triangular patches included in the conventional

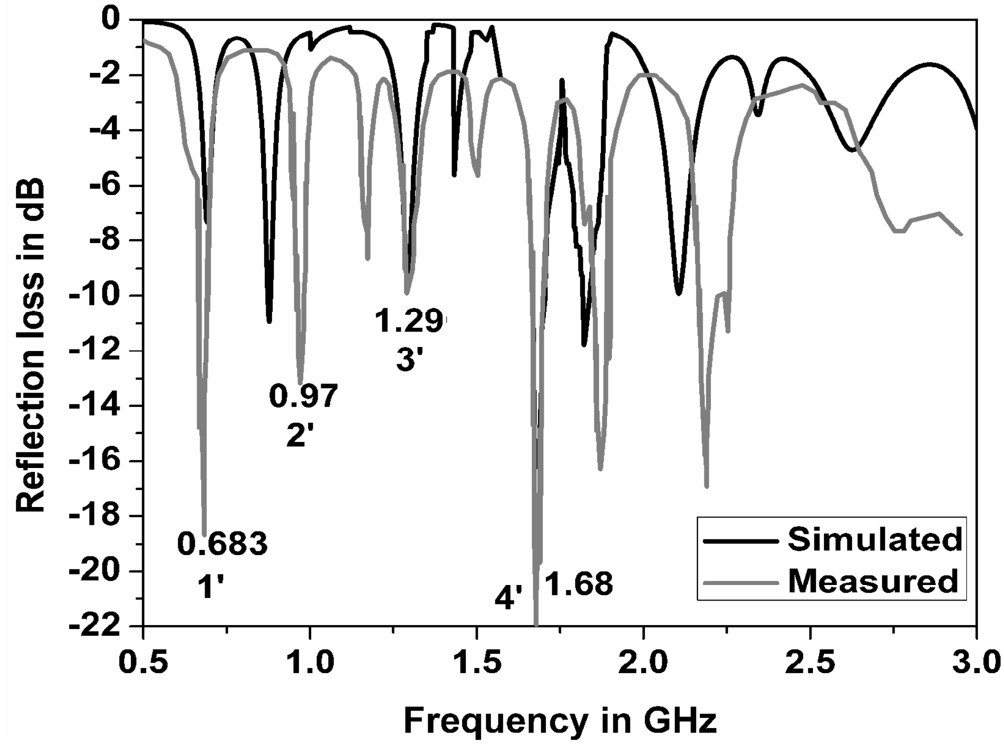

Figure 4. The reflection loss plots of probe fed proposed antenna.

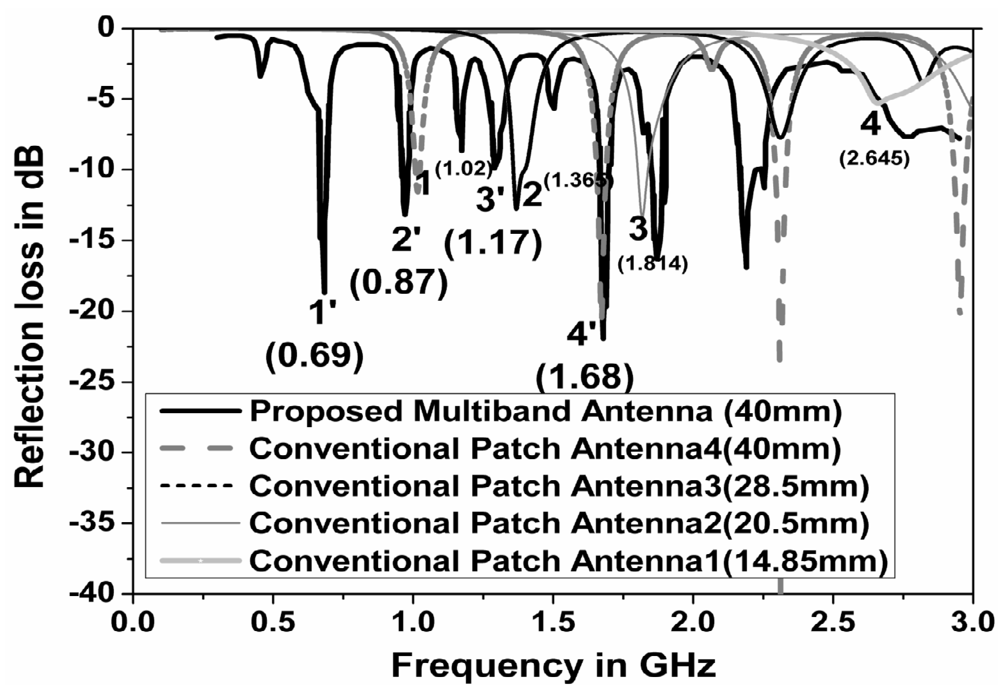

Figure 5. Simulated reflection loss plot of fourth iterated proposed antenna against conventional antennas of equivalent dimension at different iteration levels to depict miniaturization at every iteration

geometry. The major axis dimensions (d/2) of the multi-triangular patches considered are 40 mm, 28.5 mm, 20.85 mm and 14.85 mm respectively. Also, the probe fed conventional antennas of same dimensions (i.e. 40 mm, 28.5 mm, 20.85 mm and 14.85 mm respectively) are simulated and results are shown in Fig. 5 and table 1. The resulting resonating frequencies of conventional antennas are shown by numbers 1, 2, 3 and 4 corresponding to proposed antenna resonant frequencies numbered by 1', 2', 3' and 4' in Fig. 5. The reduction in these frequencies due to fractal patch is about 65% (average) compared to conventional antennas of similar patch sizes as mentioned earlier. The multiple resonating frequencies in the proposed antenna (Fig. 4); compared to the conventional antenna resonating at 1.04 GHz (table 1) indicates multi-functionality [9]-[16] due to fractal nature of the proposed geometry.

Table 1. Resonant frequencies of the fractal antenna and conventional antennas

Type of antenna	Resonant Freq.	Dimension (r)			
		40 mm	**28.5 mm**	**20.85 mm**	**14.85 mm**
Conventional circular patch	Simulated	1.02 GHz	1.365 GHz	1.814 GHz	2.645 GHz
	Measured	1.04 GHz	--	--	--
Fourth iteration proposed fractal	Simulated	0.69 GHz	0.87 GHz	1.17 GHz	1.68 GHz
	Measured	0.683 GHz	0.97 GHz	1.29 GHz	1.685 GHz
% reduction in freq. due to proposed fractal compared to conventional patch of equivalent dimension (simulated)		67.65	63.73	64.45	63.5

Also, the resonating frequency (1.04 GHz) of conventional (base) antenna reduces by 67.65% to 0.683 GHz with the proposed fourth iterative fractal antenna geometry. This indicates miniaturization [4]- [5], [11] due to the proposed iterative geometry. This miniaturization is due to the fractal slot loading [14] and space filling [1]-[4] characteristics of the antenna. The self scaling in the antenna exhibit longer wavelength independent [2]-[4] of the classical theory is mainly due to slot loading. Hence, the proposed fractal antenna resonates at lower frequency than the conventional patch antenna of same size. The multi-functionality in the iterative fractal antenna is due to self-similarity [2], [5] among the four fractal patches in the proposed antenna geometry.

3.2 Radiation Patterns

The probe fed conventional antenna and fourth iterative fractal antenna have been simulated for co and cross polarization at their first resonant frequencies and results are presented in Fig. 6 and Fig. 7.

These results show that cross polarization gain level has got reduced in proposed fractal antenna compared to the conventional antenna. The probe fed conventional antenna is found to produce the polarization difference of -3.08 dB whereas -23.66 dB in probe fed proposed fractal antenna at theta 0 deg. as shown in Table 2. This difference reaches to -50 dB at phi = 0 and theta = 90 deg. Thus, this fractal antenna is useful for low cross polarization.

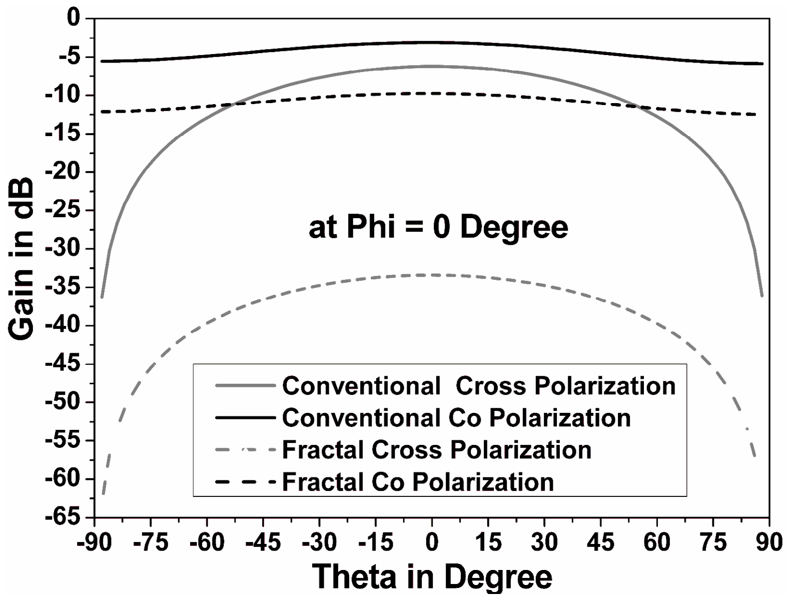

Figure 6. Co and Cross polarization gain plot of probe fed fractal antenna against conventaional antenna at their dominant resonant frequencies 0.69 GHz and 1.02 GHz respectively.

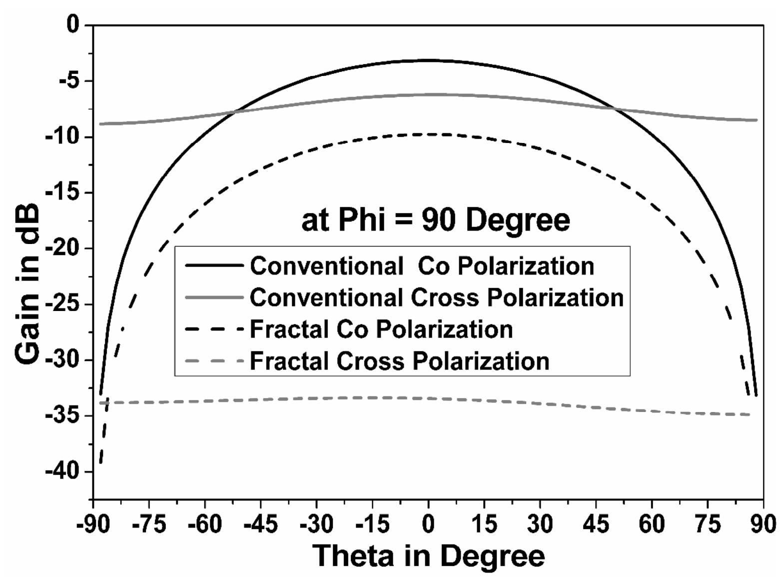

Figure 7. Co and Cross polarization gain plot of probe fed fractal antenna against conventaional antenna at their dominant resonant frequencies 0.69 GHz and 1.02 GHz respectively.

Table 2. Co and Cross Polarization Gain of Probe fed Conventional against Proposed Fractal Antenna

Theta = 0 in deg.	**Polarization**				**a-b in dB**	**c-d in dB**
	Conventional Antenna		**Fractal Antenna**			
	in dB					
	a	**b**	**c**	**d**		
Phi = 0	-3.12034	-6.20041	-9.74859	-33.40925	-3.08	-23.66
Phi = 90	-3.12034	-6.20041	-9.74859	-33.40925	-3.08	-23.66

4. CONCLUSIONS

The proposed fractal antenna can be fabricated on low cost FR4 substrate material. It is simple in design. It exhibits multiband and miniaturization properties as compared to conventional antenna. The multiband behavior of the antenna is due to self-similar multi-triangular slot loading. The fourth iterated antenna exhibits four bands corresponding to four iterations that exist in the antenna geometry. The largest size iteration (i.e. first iteration) corresponds to lowest frequency and lowest size iteration (i.e. fourth iteration) corresponds to highest frequency. The miniaturization in the fractal antenna is due to space–filling iterative geometry. The fractal nature of the multi-triangular slot further enhances the compactness feature of the antenna. The fractal antenna exhibits reduces cross polarization levels compared to conventional patch antenna. The antenna can be designed flexibly by manipulating the size of iterations for required frequencies. The fractal antenna is suitable for compact multiband wireless applications and low cross polarization. The antenna can be suitable candidature for bandwidth enhancement in future experimentation for compact broadband applications as well as radar cross section reduction for low observability.

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REFERENCES

[1] B. Mandelbrot (1983) *The Fractal Geometry of Nature*, New York: W.H. Freeman.

[2] D. H. Werner, and P. L. Werner (1996) “Frequency independent features of self-similar fractal antennas,” *Radio science*, Vol. 31, no. 6, pp.1331-1343.

[3] C. Puente et al. (1988) “Small but long koch fractal monopole,” *Electron. Lett.* , Vol. 34, issue 1, pp. 9-10.

[4] G. J. Walker, and J. R. James (1998) “Fractal volume antennas,” *Electron. Lett.*, Vol. 34, issue 16, pp. 1536-1537.

[5] Y. B. Thakare (2012) “Design of fractal antennas and their back scattering analysis,” Ph.D. dissertation, Dept. Electron. Sci., Shivaji Univ., Kolhapur, India.

[6] M. Navarro et al. (1999) “Self-similar surface current distribution on fractal Sierpinski antenna verified with infrared thermograms,” IEEE *APS Int. Symp.* , Vol.3, pp. 1566_1569.

[7] C.A. Balanis (2005) *Antenna Theory - Analysis and Design*, third edition, John Wiley & Sons.

[8] Thakare Y. B. etal. (2012) “Super wideband fractal antenna for wireless communication,” in Conf. Rec. 2012 IEEE *Int. Conf. ICWITS*, pp.1- 4.

[9] M. G. Sindou, Ablart, and C. Sourdois (1999) “Multiband and wideband properties of printed fractal branched antennas,” *Electron. Lett*., Vol. 35, pp. 181-182.

[10] Hara Prasad etal. (2000) “Microstrip fractal patch antenna for multiband communication,” *Electronic Lett.*, Vol. 36, issue 14, pp. 1179-1180.

[11] Y. B. Thakare et al. (2010) “Design of fractal patch antenna for size and radar cross-section reduction,” IET *Microw. Antennas and Propog*., Vol. 4, pp. 176-178.

[12] K. C. Hwang (2007) "A Modified Sierpinski Fractal Antenna for Multiband Application", Antennas and Wireless Propagation Letters, IEEE, Vol. 6, pp. 357-360.

[13] S. R. Anoop, K. K. Ajayan, M. R. Baiju, V. Krishnakumar (2010) "Multiband behavioural analysis of a higher order fractal patch antenna," Ultra Modern Telecommunications and Control Systems and Workshops, International Congress, pp. 823-827.

[14] Han Byul Kim, Keum Cheol Hwang (2012) "Dual-Port Spidron Fractal Slot Antenna for Multi-band Gap-Filler Applications," IEEE *Trans. Antennas and Propagation*, Vol. 60, no. 10, pp. 4940-4943.

[15] Y.X. Guo, I. Ang, M. Y. W. Chia (2003) "Compact internal multiband antennas for mobile handsets," IEEE *Antennas and Wireless Propagation Letters*, Vol. 2, pp. 143-146.

[16] S. Chaimool, C. Chokchai, P. Akkaraekthalin (2012) "Multiband loaded fractal loop monopole antenna for USB dongle applications," *Electronics Letters* Vol.48 issue23, pp.1446-1447.

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Short Biography

Yogesh B. Thakare (mother-Sushilabai) is passed BE E&TC in the year 1998 with first class from VYWS College of Engg., Badnera, Amravati University (Maharashtra -India), ME E&TC (Microwave) in the year 2006 from Govt. College of Engg., Pune, Pune University (Maharashtra-India) in first class and Ph.D. (Electronics) from Shivaji University, Kolhapur (Maharashtra- India) in 2015. He has about 15 years teaching and 02 years industrial experience. He is currently working with PVG's College of Engineering and Technology, Parvati, Pune (Maharashtra-India) as ASSISTANT PROFESSOR in the department of electronics and telecommunication Engg. He taught major subject like wave theory and ante nna, microwave engineering, semiconductor devices and technology, analogue and digital communication engineering. He has 04 international and 01 national journal and 05 international and 04 national conference publications. His current research interest is in wave propagation techniques, microstrip antenna engineering, communication engineering and semiconductor electronics.