DESIGN OF TRIPLE-BAND CPW FED CIRCULAR FRACTAL ANTENNA

Naresh Kumar Darimireddy[1], R. Ramana Reddy[2] and A. Mallikarjuna Prasad[3]

[1]Research Scholar, JNTUK, Kakinada, AP, INDIA

[2]Department of ECE, MVGR College of Engineering, Vizianagaram, AP, INDIA

[3]Department of ECE, UCEK (A), JNTUK, Kakinada, AP, INDIA

ABSTRACT

A novel miniaturized circular fractal antenna is designed by inscribing circular slot on rectangular ground plane and successively forming circular rings connected by semi-circles for circular-fractal patch. Novel modified Coplanar Waveguide (CPW) is used as feed for fractal circular patch. The analysis of parametric variations is performed by consecutive fractal iterations, varying the radius of inscribed circle of ground plane, slots and different ground plane configurations. To further enhance gain and radiation pattern a dual inverted L slots is included in ground plane. From the results it is evident that, the proposed fractal antenna possesses triple bands at 1.8GHz, 3.5GHz and 5.5GHz. These bands are used in Digital Communication Systems (DCS) (1.8GHz), IEEE 802.16d fixed WiMAX (3.5GHz) and IEEE 802.11a WLAN (5.5GHz) applications.

KEYWORDS

Fractal Geometry, Circular fractal Antenna, WLAN/WiMAX, Coplanar feed, Slotted ground plane

1. INTRODUCTION

The wireless standards of WLAN/WiMAX low frequency applications, require miniaturized and compact antennas. Low and medium fixed channel capacity point-to-point links uses the Digital Communication System (DCS) or GSM1800 frequency band. In order to gratify the IEEE WLAN standards in the 2.4 GHz and 5-6 GHz bands, a single antenna with multiple bands is needed. The proposed IEEE 802.11a 5.5GHz standard handles higher throughput and data rate at 1Gbps compared to 2.4GHz band where there is a huge traffic of data transmission. The IEEE 802.16d fixed 3.5/5.8 GHz WiMAX standard available for diverse broadband high speed data transmission [1]. The application of fractal geometry on antennas is one of the methods, which provides multi frequency operating band capability.

Fractals are quantitatively curved shapes, which are self-similar, repeating themselves at various scales [2]. Utilizing the fractal geometry in a patch antenna increases the length, or maximize the perimeter (inner or the outer structure), of patch that can collect or broadcast electromagnetic radiation within a total given surface area or volume [3]. The self-similarity and space-filling are the main properties, as the fractal geometries are mathematically linked to its frequency characteristics of the antenna [4]. The use of coplanar ground plane makes the new inscribed circular triangular fractal design conformal and more suitable for the ultra wideband and miniaturized applications [5]. Generally fractal designs are meant for their multi and wideband operation and also these designs are optimized for UWB characteristics [6].

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Different techniques have been introduced to get desired and unwanted sub bands in UWB domain. Most prominent examples are inserting a T-stub in the patch element or dual strips of parasitic in nature beside the feed or by inserting quarter wave and half wave split ring resonators or embedding H-slot in the patch. Another way is to embed the arc-shaped parasitic patch besides the radiating element or inserting various slots in the feed [7]. A novel way of applying fractal geometry approach to produce multi bands in an miniaturized fractal antenna due to space filling and self similar properties, which in turn enhances the valuable electrically effective length to minimize the area of the patch element [8-10].

In this paper, the design of a novel tri-band coplanar waveguide fed circular fractal antenna is proposed for modern era of wireless communication applications..

2. ANTENNA GEOMETRY

The proposed fractal antenna geometry with designated dimensions is shown in Figure 1. The proposed fractal antenna with substrate of FR4-epoxy (ε_r) =4.4 having dimensions 25 × 26 mm^2 (L × W) with height (h) = 1.6mm. The rectangular ground plane is inscribed with a circle of radius R_1=10.7mm and radiating patch is constructed with circular rings R2=8mm, R3=6mm and R4=4mm where each rings are 1mm wider and 1mm apart. All the rings are connected through a radius of 1.1mm semi circles. The ground plane is modified with W_5=5mm and a pair of inverted L slots of 2×2 mm^2 (L_2×W_2) with a W_6=0.5mm is inserted. The coplanar ground plane is having a strip of W_3=1.9mm. The gap between patch feed and ground plane is W_4=1mm.

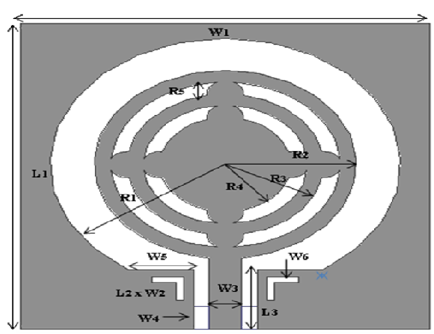


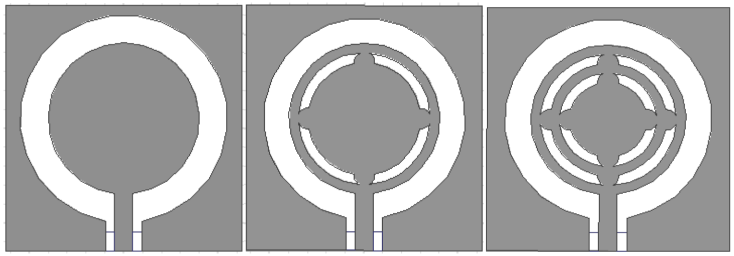
Figure 1: The proposed circular fractal antenna

3. PARAMETRIC ANALYSIS

The fractal antenna is designed and simulated using ANSYS HFSS 14.0 software package. The performance of the proposed circular fractal antenna is estimated using parametric studies of different fractal iterations, radius R1 of ground plane, various ground plane structures and different feed gap values of W_4 and W_5 are presented below.

3.1. EFFECT OF FRACTAL ITERATIONS

The self similar fractal iterations are performed as shown in Figure 2 (a)-(c) and their results are observed with respect to S11, VSWR, Gain and Radiation Pattern.



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

Figure 2: Successive Fractal Iterations

The corresponding results of fractal iterations of antenna are plotted in Figure 3-4 and tabulated in Table 1. Among all, the third iteration is having better return loss, gain of 3.75dB VSWR lesser than 1.5 and an offered bandwidth of 800MHz at 3.5GHz and 750MHz at 5.5GHz.

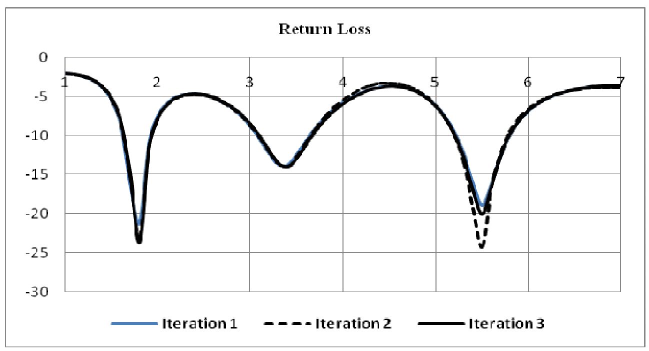


Figure 3: S11 versus frequency for all fractal iterations

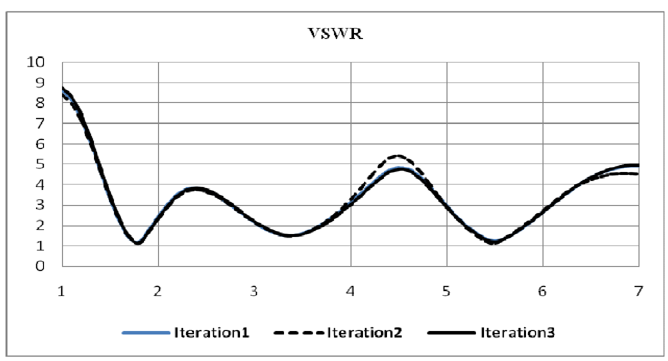


Figure 4: VSWR for all the fractal iterations

Table 1: Results of circular fractal iterations

Sl.No	Resonant Frequencies (GHz)	Return Loss (dB)	VSWR	Bandwidth (MHz)	Gain (dB)
Iteration 1	1.8	-23.2	1.05		3.65
	3.4	-14.5	1.5	550	

Sl.No	Resonant Frequencies (GHz)	Return Loss (dB)	VSWR	Bandwidth (MHz)	Gain (dB)
	5.5	-19.2	1.1	600	
Iteration 2	1.78	-23.5	1.1		3.72
	3.4	-14	1.5	550	
	5.5	-24.2	1.1	600	
Iteration 3	1.8	-32.5	1		3.75
	3.5	-17	1.25	800	
	5.5	-29.2	1.05	750	

3.2. Effect Of Radius R_1 of Ground Plane

The inscribed circle of radius R_1 of ground plane is varied by keeping other patch elements constant and their results are shown in Figure 5. The proposed dimension for inscribed circle of ground plane R_1=10.7mm.

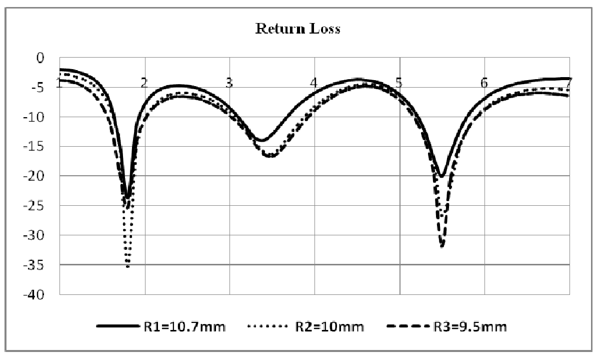
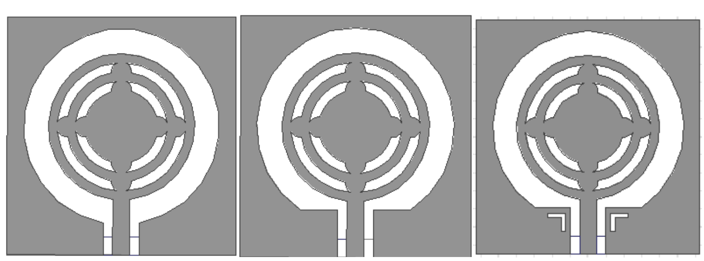


Figure 5: S11 versus frequency for different values of R_1

3.3. Effect of Different Ground Plane Variations

Three different configurations of ground planes are presented in Figure 6. Among all Ground plane 3 with L slots is proposed and the corresponding return losses of -25dB at 1.8GHz, -15.6dB at 3.5GHz and -47dB at 5.5GHz are shown in Figure 7.



(a) Ground plane 1 (b) Ground plane 2 (c) Ground plane 3

Figure 6: Three different configurations of ground planes

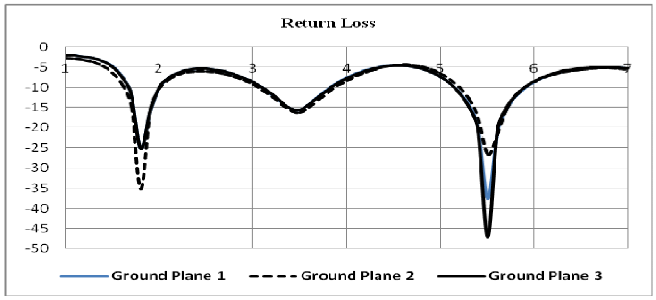


Figure 7: Return loss observations for different ground planes

3.4. EFFECT OF W_3, W_4, W_5

The effect of feed line width W_3, gap between ground and feed of the patch (W_4), and W_5 is observed for different values by keeping W_1, W_2 and W_6 constant. From Figure 8 it is evident that, for the proposed W_4=1mm and W_5=4mm the antenna resonates at 1.8GHz (GSM1800), 3.5GHz (IEEE 802.16d fixed WiMAX) and 5.5GHz (IEEE 802.11a WLAN). For W_4=0.85mm when W_3=2.2mm the possesses 1.9GHz, 3.5GHz and 5.6GHz.

For W_4=0.5mm and W_5=5mm, the antenna resonates at 2GHz (Advanced Wireless Services i.e. Mobile Satellite services), 3.7GHz and 5.8GHz (IEEE 802.16d WiMAX). For W_4= 0.5mm without L slot, the antenna resonates at 1.9GHz (DECT-Digital Enhanced Cordless Telecommunications), 3.7GHz (IEEE 802.11y extended version of 802.11a), 5.725GHz (ISM band). The above triple band proposals are quite good and they can cover multiple wireless applications. From Figure 9 it is observed that, all the proposals are having VSWR<=1.5 as per industry standard.

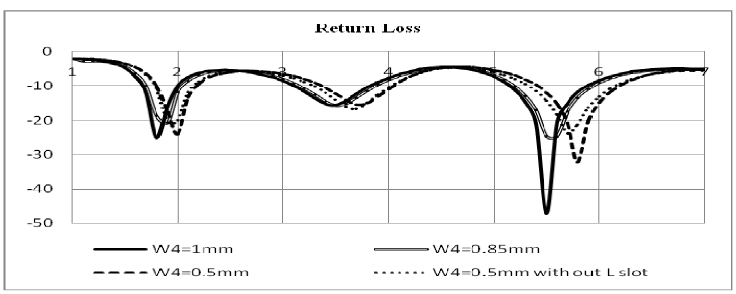


Figure 8: S11 versus Frequency observations for different gaps (W_4)

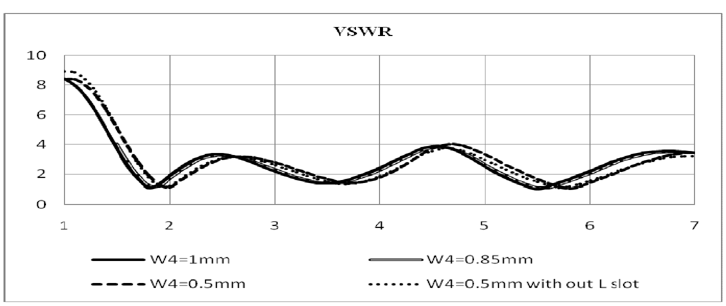
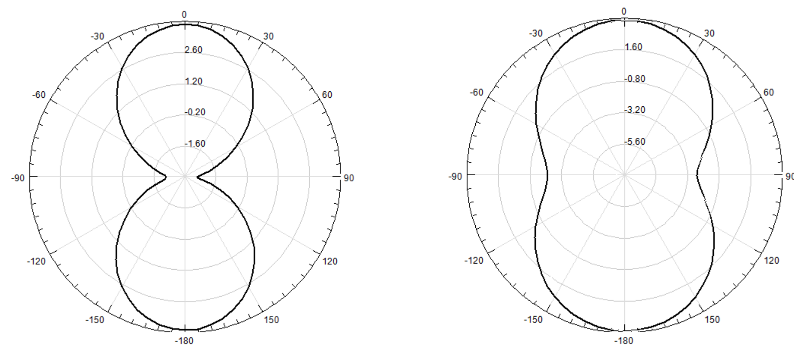


Figure 9: VSWR observations for different gaps (W_4)

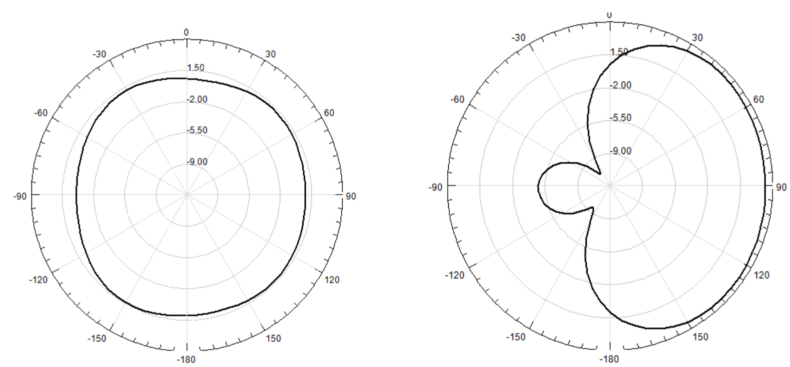
3.5. RADIATION CHARACTERISTICS

The far field radiation patterns of the proposed circular fractal at the resonant frequencies (3.5GHz and 5.5GHz) are shown in Figure 10-11. The E and H-Plane patterns of the antenna at resonant frequencies are shown below.



(a) (b)

Figure 10: Radiation patterns at 3.5GHz (a) E-Plane (b) H-Plane



(a) (b)

Figure 11: Radiation patterns at 5.5 GHz (a) E-Plane (b) H-Plane

Figure 10 shows that the E-plane pattern exhibits dual band and H-plane provides almost wide band characteristics at 3.5GHz. Figure 11 shows that E-plane pattern possesses omni-directional and H-plane provides wideband characteristics. The antenna has a gain of 3.7dBi at 3.5GHz and 4.5dBi at 5.5 GHz solution frequencies.

4. CONCLUSIONS

In this paper, a novel miniature triple-band fractal antenna is designed by successive self similar circular rings are connected with semi circles and it is fed by CPW feed. The parametric studies of fractal antenna with respect to number of iterations, different inscribed circle radius R_1 in ground plane, various ground plane structures and different gap widths between ground and feed are performed and analyzed in this paper. The proposed circular fractal antenna has triple bands at

Digital Cel1ular System (GSM1800), WiMAX (IEEE 802.16d at 3.5GHz) and WLAN (IEEE 802.11a at 5.5GHz). From the results it is evident that the proposed antenna offers a bandwidth of 800MHz, a peak gain of 3.5-4.5dBi and the antenna has good radiation characteristics.

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AUTHORS

Mr. Naresh Kumar Darimireddy received B.Tech. in ECE from, NBKRIST, Sri Venkateswara University, Tirupati, and M.E. (EC) in UVCE (A), Bangalore University, Bangalore, M.B.A (General) from Pondicherry Central University and Pursuing Ph.D. in JNTUK, Kakinada. He is having around 12 years of Teaching and Industry Experience. He is a member IE and qualified UGC-NET June 2013 for Lectureship in Electronic Science. His research interests include RF & Microwave Engineering and Signal Processing.

Dr. R. Ramana Reddy did AMIE in ECE from The Institution of Engineers (India) in 2000, M.Tech (I&CS) from JNTU College of Engineering, Kakinada in 2002, MBA (HRM & Marketing) from Andhra University in 2007 and PhD in Antennas in 2008 from Andhra University. He is presently working as Professor & Head, Dept. of ECE in MVGR College of Engineering, Vizianagaram. Coordinator, Center of Excellence – Embedded Systems, Head, National Instruments Lab VIEW academy established in Department of ECE, MVGR College of Engineering. Convener of several national level conferences and workshops. Published about 70 technical papers in National/International Journals / Conferences. He is a member of IETE, IEEE, ISTE, SEMCE (I), IE, and ISOI. His research interests include Phased Array Antennas, Slotted Waveguide Junctions, EMI/EMC, VLSI and Embedded Systems.

Dr A. Mallikarjuna Prasad, Professor and HOD of ECE, UCEK (A), JNTUK, Kakinada. He obtained his Ph.D from Andhra University. He is presently HOD, Department of ECE, UCEK(A), JNTUK. He worked as Controller of Examinations in JNTU-K. His research interests include Wireless Communications, Biomedical Instrumentation and Microwave antennas.