The International Journal of Engineering And Science (IJES)
||Volume|| 1 ||Issue|| 2 ||Pages|| 308-312 ||2012||
ISSN: 2319 – 1813 ISBN: 2319 – 1805

An Innovative Octagonal Fractal Circular PIFA for Mobile Phone Applications

[1] S. Beril, [2] T. Anita Jones Mary
Department of Electronics and Communication, Karunya University

Abstract

Usually cell phones operate in different bands which require multiple antennas to be designed for different applications. Planar Inverted F Antenna (PIFA) is popular for portable wireless devices because of its low profile, small size and simple structure. Narrow Bandwidth still remained as a problem even after using PIFA. But by using fractal PIFA antennas multiple bands have been achieved with a single antenna without significant increase in space. Also octagonal shape and slotted structures in the circular patch helps in increasing bandwidth. In this paper Octagonal Fractal slotted Circular PIFA has been proposed and designed using FEKO. The results show that the proposed antenna can be used for integrating telecommunication services such as GSM, 3G, HiperLAN, UMTS and WLAN in mobile phones with good efficiency and gain.

***Keywords** - Bandwidth, Fractal antenna, Mobile Phones, Octagonal antennas, Planar Inverted Fractal Antenna (PIFA).*

Date of Submission: 13, December, 2012 ⟺ Date of Publication: 30, December 2012

I. Introduction

When the cell phones were first introduced in the early days, they were very large in size and had very limited service areas. Cell phones had large antennas that have to be pulled out before making a phone call. Cell phone antennas may seem like a fairly harmless issue but it is not so. Only when the antenna is more efficient, less power is consumed by the device. This is possible only when the size of the antenna is small.

There has been an increasing demand in antennas that are compact, conformal, and broadband. A popular method of achieving these characteristics in an antenna is by exploiting the property of fractals. Applications for fractal geometries in cellular devices have become hot topics of research because of consumer demand. Fractal antennas take advantage of delivering exactly what consumers need. Fractal geometries have two common properties namely self-similar property and space filling property. The self-similarity property results in a multiband behaviour of the fractal antennas [1]. Using the self-similarity property a fractal antenna can be designed to receive and transmit over a wide range of frequencies. Space filling property is used mainly to reduce antenna size. Fractal antenna uses a self-similar design to maximize the length of a material with a total surface area. This makes fractal antennas compact and wideband. The fractal element of the antenna allows it to have much different resonance, i.e. it will act as an antenna for many different electromagnetic frequencies. The different resonances arise because of the fractal nature of the antenna.

In Multi-Band Microstrip Rectangular Fractal Antenna [1] using a decomposition algorithm, compactness has been obtained. For reducing the size of the antenna, Fractal geometries have been introduced in the rectangular microstrip antenna. The aspects of microstrip antennas such as the design have been studied in this paper and the size of the antenna has been greatly reduced. Different theories and techniques for shrinking the size of an antenna through the use of fractals have been discussed in [2]. Fractal antennas can obtain radiation pattern and input impedance similar to a longer antenna but take less area due to the many contours of the shape.

The design and performance of three fractal loop antennas for passive UHF RFID [3] tags at 900 MHz was investigated. Fractal loop had better radiation characteristics than the standard Koch fractal loop. Fractal antennas gained their importance because of its features of miniaturization, wideband, multiple resonance, low cost and reliability. The antenna satisfied all the requirements in reducing the RFID tag size and cost by providing good impedance matching and high gain.

Fractal PIFA antenna also [4] has been proposed to achieve the design of internal compact and broadband microstrip patch antennas. This paper proposes a fractal which can be used as an internal antenna solution with a wideband frequency response which covers the required operating frequency range for mobile phone application.

A comparison among the three designs has been presented in [5] which show that the Sierpinski carpet fractal antenna is better than the other two fractal designs Sierpinski carpet and Koch curve. The carpet design exhibits a bandwidth of 1.8 GHz which is comparable to the other designs where as it has demonstrated a size of reduction of 53 % which is greater than the two fractal designs.

The accomplishment of acceptable bandwidth is definitely an important consideration for antenna design in mobile communications systems. The radiation pattern result shows an omnidirectional radiation, which can radiate equally in all directions which entails that the antenna is suitable for application in wireless communication, especially in the desired domain. SCF-PIFA [6] effectively reduced the element size as compared to the printed microstrip transmission line feed Sierpinski Carpet antenna and was able to provide coverage at all desired frequency bands.

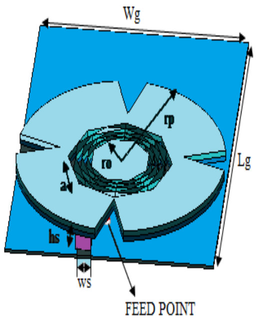
The Fractal Microstrip patch antenna is also used in backscattering reduction. The radiation pattern of fractal antenna in [7] shows that cross polarization level is better in fractal patch. The gain loss of Fractal antenna compared with rectangular antenna on resonant frequency is less than 1 dB. It has been found that this structure with proper indentation in the border length offers considerable miniaturization compare to the conventional rectangular patch antenna. As the iteration order increases, the resonant frequency decreases more to lower side and indicates more size reduction. Such properties of the patches make it possible to apply fractal antennas to those applications needing reduced size of antennas.

Currently, many cell phones use a Planar Inverted-F Antenna (PIFA), which is small, low-profile antenna. The Planar Inverted-F antenna [8] is used in the mobile phone market in a large extent. The antenna is resonant at a quarter-wavelength and hence it reduces the space occupied in mobile phones. This antenna is similar to the shape of inverted F [9], coordinating its name. The Planar Inverted-F Antenna has a low profile and an omnidirectional pattern.PIFA consists of three parts namely, rectangular planar element, ground plane and short-circuit plate. The drawback is its narrow bandwidth and not multiband. Fractal PIFA has been designed to address these problems. A Fractal PIFA [10] works similarly to a traditional PIFA, but has fractal design. As the fractal PIFA's serve as an effective internal antenna with good efficiency and gain, its efficiency could still be increased using octagonal printed patches and bandwidth could be increased using slotted patches [11] which have been designed in this paper.

II. Proposed Antenna Design

The proposed antenna iterations are constructed on a circular radiating patch of radius r with a thickness 1mm which is printed on a Rogers board of same radius r with a thickness of 0.813mm and ϵ_r of 3.38 where r [12] is given by

$$r=1.306(\lambda/2)\ \text{mm} \qquad (1)$$



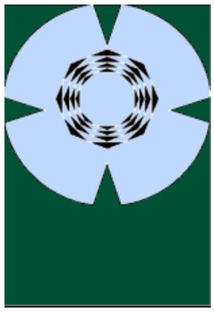


Fig.1 Proposed Antenna **(a)** Basic geometry (b) Top view

Rogers board is connected to the ground plane measuring Lg x wg through a stub measuring hs x ws which supports the whole antenna. The configuration of the proposed PIFA is shown in Fig.1.

TABLE I
PIFA PARAMETERS

Parameter	Value (mm)
Lg	100
wg	54
rp	54
hs	7
ws	4
r0	10
a	5

Depending on the Fractal's iterations the stub and feed position can be varied. The parameter of the proposed antenna has been given in the Table I. A perfect fractal antenna would be obtained by iterating the simple Cantor array an infinite number of times.

Fig.2 shows the antennas bearing zeroth iteration with line as a radiating element. Zeroth iteration (or) base shape is obtained without iteration by inserting the cuts in the four sides. First iteration which is shown in figure is obtained by printing a single octagon on the circular patch centre of radius 'r0'. Figure shows the second iteration obtained by iterating the middle octagon of side 'a'.

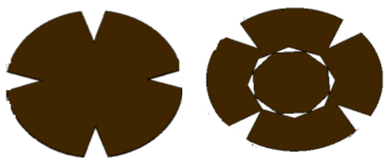


Fig.2 Fractal PIFA for (a) zeroth iteration fig 3(b) first iteration

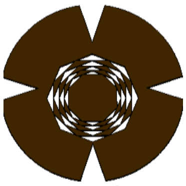


Fig 3(c) second iteration

Octagonal shape has been selected as it gives a high bandwidth [13, 12].The bandwidth of the antenna can be improved when the available planar area of a circle of radius r is best utilized by the antenna. The end V shaped structures also helps to improve bandwidth. The stub kept vertically provides better matching and tuning. A circular patch [14] with a single feed point will create linear polarization. If the circular patch antenna is made into an ellipse and fed properly it can produce circular polarization. Standard circular shape patch antenna has linear polarization. Changing the position of the feed point, horizontal or vertical polarization can be obtained. Circular polarization can also be obtained by making some slots or slot like structures. The slot affects not only the polarization, but also improves antenna impedance. It is also easy to fabricate patch antennas that radiate circularly-polarized waves. Fractal PIFA [15] design has allowed for a large Bandwidth after few iterations.

V. Antenna Results and Discussions

TABLE II
BANDWIDTH RESULTS OF THE ANTENNA

Iterations	Frequency (MHz)	Bandwidth(MHz)
Zeroth	1900-2400	500 (8.75%)
First	2000-2900(1st resonance)	900(11.53%)
	3000-3800(2nd resonance)	800(8.19%)
	4000-4700(3rd resonance)	700(11.36%)
Second	5500-6900	1400(24.13%)

The proposed antenna has been simulated using FEKO. Except the dielectric Rogers board, the ground plane and all conductors are assumed perfect electric. This fractal antenna can be used for integrating many telecommunication services like GSM, Blue tooth, HIPERLAN, WLAN and 3G services. Fig. 3 shows the simulated return loss measurements (S_{11}) for three iterations of the proposed antenna. From the return loss graph the measured bandwidths are as follows: For iteration 0, the bandwidth is 500 MHz (1900-2400Mhz), while for the first iteration it is 900 MHz (2000-2900Mhz) in the lower band, 800 MHz (3000-3800 MHz) in the middle band, 700Mhz (4000-4700)MHz in the upper band and for third iteration the bandwidth is 1400 (5500-6900 MHz).The results have been tabulated in Table II.

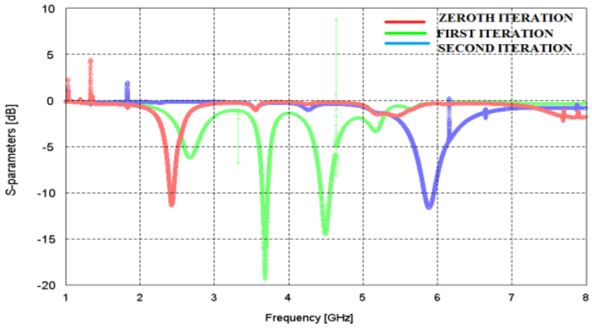


Fig.3 Return loss

The bandwidth has been calculated and the values are tabulated in table II. Bandwidth describes the range of frequencies over which the antenna can properly radiate or receive energy. It has been found that as the iteration increases, bandwidth has been increased in our proposed antenna. Iteration of the antenna supports dual band operation whereas without iteration antenna possess only single band of operation. The fundamental operating resonant frequency is about 2.4 GHz with an operating Bandwidth of 500 MHz.

TABLE III
EFFICIENCY RESULTS OF THE ANTENNA

Telecommunication Service	Frequency (MHz)	Efficiency (%)
GSM	1900-2400	97.1275
3G	2000-2900	86.9757
WLAN and Bluetooth	3000-3800	90.9757
HiperLAN	4000-4700 5500-6900	79.6994 90.9757

A highly efficient antenna has most of the power present at the antenna's input. It can be seen from the Table III that the antenna radiation efficiency is more than 70%. From the obtained results of Bandwidth and efficiency given in the Tables II and III it has been shown that the proposed antenna is suitable for being used as an internal antenna for mobile communication.

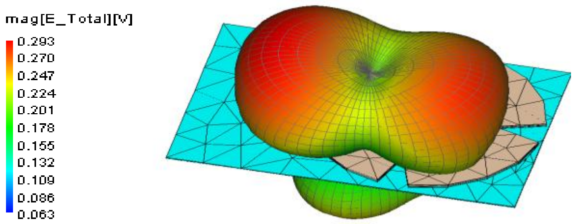


Fig.4.Radiation pattern

Fig.4 shows the 3D radiation pattern of the antenna which defines the variation of the power radiated by an antenna as a function of the direction away from the antenna.Radiation pattern obtained at the first, second and third frequency is almost omni-directional, and is well suited for mobile phone applications. The omni directional pattern provides the widest coverage making the mobile phone antennas wide access to a large number of cell phone tower access points.

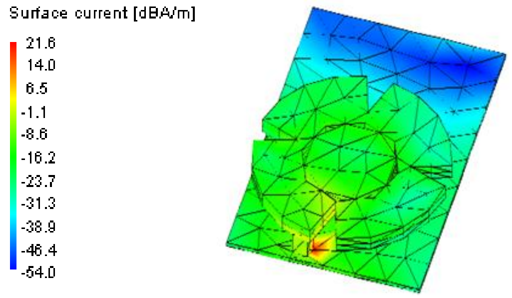


Fig.5.Current distribution

Fig. 5 shows the current distribution in the antenna. The current will be zero at the end of the ground plane and the voltage is out of phase with the current. Hence the voltage is at a peak at the end of the patch and near the start of the feed; the voltage has equal magnitude but out of phase which produces fringing fields that coherently add in phase and produce radiation which is maximum near the feed point.

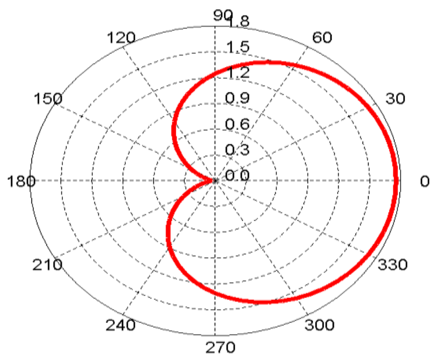


Fig.6.Gain

Due to the properties of the Fractal antenna, the proposed geometry of an antenna is very versatile in term of polarization, radiation pattern, gain and bandwidth. Through proper selection of the feed, reduction in size of the antenna with higher iterations and bandwidth enhancement can be observed clearly in the proposed geometry. Fig .6 shows the antenna gain which gives the amount of power transmitted in the direction of peak radiation. An antenna with a gain of 3 dB means that the power received far from the antenna will be 3 dB higher than what would be received from a lossless isotropic antenna with the same input power. Most advanced mobile tactical communications in the world have been enabled by high gain fractal antennas.

IV. Conclusion

In this paper, the octagonal Fractal shapes with different iterations are employed and studied in a detailed manner. The main aspect in the design of typical circular patch microstrip antenna is the V shaped structures at its ends which improves the bandwidth and efficiency. A good impedance matching and gain has also been achieved by this antenna. This antenna could be used for mobile phones for integrating various telecommunication services as multi-band [16] frequencies (2.3 GHz, 2.6 GHz, 3.7 GHz, 4.5 GHz, and 5.9 GHz) has been obtained.

References

[1] Tong, chin hong matthew .," System study and design of broad-band U slot microstrip patch antennas for aperstructures and opportunistic arrays" December 2005

[2] Nemanja Popržen, Mićo Gaćanović.,"Fractal Antennas: Design,Characteristics And Application" *IEEE., proceedings* 2011

[3] http://www.antenna theory.com/

[4] A. Azari," Ultra wideband fractal microstrip Antenna design"*Progress In Electromagnetics Research* C, Vol. 2, 7–12, 2008

[5] C. A. Balanis, *Antenna Theory: Analysis and Design.* New York: Wiley, Second ed.1997

[6] B. J. Kwaha, o. N inyang p. Amalu,"The Circular Microstrip Patch Antenna – Design And Implementation" International Journal of Research and Reviews July 2011.,vol8

[7] Ahmed M. A. Sabaawi and Kaydar M. Quboa,"Design and Fabrication of Miniaturized Fractal Antennas for Passive UHF RFID Tags" Advanced Radio Frequency Identification Design and Applications.,2010

[8] "A Comprehensive Parametric Study of Planar Inverted-F Antenna" Hassan Tariq Chattha1, Yi Huang, Muhammad Kamran Ishfaq, Stephen J. Boyes., *Wireless Engineering and Technology*, 2012,

[9] Abolfazl Azari,"A New Super Wideband Fractal Microstrip Antenna"*IEEE Transactions On Antennas And Propagation*, Vol. 59, no. 5, may 201

[10] Prashant More Sanjay V. Khobragade., "A Hexagonal-Shaped Fractal Antenna Array for Multiband Applications" Proceedings of International Journal of Computer Applications.,2012

[11] Wael Shalan, and Kuldip Pahwa,"Multi-Band Microstrip Rectangular Fractal Antenna for Wireless Applications*" International Journal of Electronics Engineering*, 2011, pp. 103– 106

[12] N.A. Saidatu , P.J. Soh , Y. Sun, D. Lauder, A.A.H. Azremi ,"Multiband Fractal PIFA (Planar Inverted F Antenna) for Mobile Phones" *IEEE conference on communication*.,Sept. 2010

[13] http://www.fractenna.com/

[14] N.A. Saidatul, A.A.H. Azremi, R.B. Ahmad, P.J. Soh.,"A Design of Dual Band Sierpinski Carpet Fractal Planar Inverted F Antenna (PIFA) for GSM 1800/1900, UMTS and HiperLAN Application"

[15] Pekka Salonen, Lauri Sydänheimo, Mikko Keskilammi, Markku Kivikoski,"A Small Planar Inverted-F Antenna for Wearable Applications"*Proceedings of the IEEE International Symposium* .,1999

[16] "A New Fractal Based PIFA Antenna Design for MIMO Dual Band WLAN Applications" *PIERS Proceedings*, Kuala Lumpur,MALAYSIA, March 27, 2012

[17] Farhan A. Ghaffar, Atif Shamim, Khaled N. Salama*.,"*Design and Comparison of LTCC Based Fractal Antennas"proceedings of ursi.,2011

[18] Raj Kumar and P. Malathi.," On the Design of Fractal Patch Antenna and Backscattering Reduction"*International Journal of Recent Trends in Engineering*, Vol 2, No. 7, November 2009

Biographies and Photographs

S.Beril was born in India on 20th April 1990. She has received B.E degree in Electronics and Communication Engineering and currently doing her Master of technology in Karunya University.She has got professional membership in IAESTE and IAENG.

T. Anita Jones Mary was born in India on 8th May 1976. She has received B.E degree in Electronics and Communication Engineering from Madurai Kamaraj University, in 1998.She has received M.E degree in Communication Systems from Madurai Kamaraj University, in 2000. Currently she is pursuing PhD degree in Design of MIMO antennas for wireless applications.