

Irregular Circular Fractal Slot Antenna for Dual Wideband Applications

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ABSTRACT

A compact CPW-fed fractal circle monopole antenna with dual wideband is presented for simultaneously satisfying wireless local area network (WLAN) for 2.4/5.2/5.8 GHz application. The antenna consists of irregular shape circles based on the Descartes circle theorem. The simulated -10 dB bandwidth for return loss is from 2.04 to 3.35 GHz and 4.96 to 5.9 GHz, covering all the 2.4/5.2/5.8 GHz WLAN Bands obtained. It is observed that the gain of proposed antenna for 2.4 GHz and 5.2 GHz is 3.606 dBi and 5.96 dBi respectively. This antenna gives stable monopole-like radiation patterns.

Keywords

Dual wide band; Circular Antenna; Fractal Antenna; CPW-fed; Descartes Circle Theorem

1. INTRODUCTION

Recently, the ability to integrate more than one communication standard into a single system has become an increasing demand for a modern portable wireless communication device. However, it is difficult to simultaneously set the dual or multiple antennas and a diplexer into such a device due to the limited space of device. This indicates that a modern antenna requires not only the function of providing a dual- or multiband operation, but also a simple structure, compact size, and easy integration with the system circuit. For this, many promising dual- or multiband planar antenna designs such as the as microstrip-fed printed double-T monopole [1], dual loop antenna [2] and reduced size PIFA [3] were proposed to provide dual-band characteristics to cover the 2.4/5.2 and 5.8 GHz Wireless local area network (WLAN) bands. However, these antennas could not provide uniform omnidirectional coverage. The printed dipole antenna reported in Ref. [4] incorporates two separate dipoles of different arm lengths printed on both sides of the dielectric substrate for dual band operation. The longer and shorter dipoles were designed to generate resonant radiation at 2.4 and 5.2 GHz bands. The primary limitation of this kind of design is large size of antenna and limited bandwidth. In dual-band dipole antenna reported by Su et al. [5], two resonances were obtained by cutting a U-slot in arms of the dipole. Other dual-band antenna reported by Yang, F et al. [6], the two resonances were obtained by cutting an E-slot in arms of the antenna. Wu et al. [7] reported a dual broad band slot antenna, in which the two wide resonances were obtained by using a U-shaped strip inset at the center of slot antenna. The dual-band WLAN dipole antenna proposed by Zhang et al. [8].

In fractal electrodynamics, fractal geometry is used to investigate a new class of radiation, propagation, and scattering problems. One of the promising researches is antenna theory

and design using the fractal concept [9]. Most fractal objects have self similar shape, with different scale [10, 11]. The fractal shape carried out by applying the infinite number of iteration using multiple reduction copy machine (MRCM) algorithm [12]. On the other hand, a circular generator with a non-constant fractal ratio dependent on the Descartes Circle theorem in CPW-fed structure is reported for dual and wideband antennas [13-15].

A simple and compact design of a dual band printed antenna operating at 2.4/5.2/5.8 GHz band is proposed for in this paper. The proposed antenna, designed for the WLAN applications, retains the advantage in terms of size when compared to the ultra wide band slot antennas tailored for the FCC approved UWB band (3.1–10.6 GHz), in spite of the lower frequencies of operation [16]–[19]. The design of the antenna was performed and optimized using CST Microwave Studio Suit™ 2010 based on three dimensional finite integration time-domains (FITD) method. This antenna also provides the detail study of different iteration, radiation pattern and gain and the EM characteristics by surface current distribution.

2. ANTENNA DESIGN

The proposed dual wideband Circular fractal antenna is shown in Fig. 1. The classical fractal circle shape antenna is reported in [19]. The following design is based on the principle of Descartes circle theorem with different radius [15].

If four mutually tangent circles have curvatures k_i (for $i=1,2,\dots,4$),

Then, the curvatures satisfied the relation [13-14]

$$(k_1+k_2+k_3+k_4)=2(k_1^2+k_2^2+k_3^2+k_4^2)$$

Where, $k_1=1/R_{k1}$, $k_2=1/R_{k2}$, $k_3=1/R_{k3}$, $k_4=1/R_{k4}$

And radius of the circles are R_{k1} , R_{k2} , R_{k3} , R_{k4} .

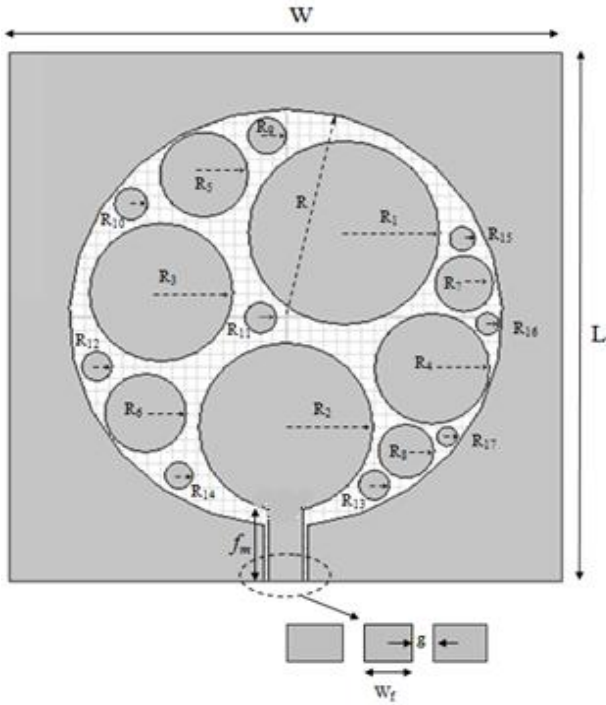


Fig.1 Geometry of proposed circle Fractal Antenna

Fig. 1 shows, geometry of the proposed irregular circular fractal slot antenna with Descartes circle theorem for dual wideband (2.4/5.2 GHz WLAN) application. The design procedure of the antenna consists of four stages. For, first stage configuration four circles are obtained by DC theorem without common tangent of different circles radius. Hence, next stage is to specify the size of circles from any set of the four original circles. Using the following set of circles in second stage eight circles are obtained. Similarly in third stage, a set of all eight circles with different radius are iterated for next stage. At final stage total seventeen circles are obtained using second and third stage of the modified irregular circles fractal slot antenna. Detailed of the iterative model which is satisfied the curvature is reported [17].

Modified antenna is constructed through four iterations and printed on an FR-4 substrate (thickness $h=1.6$ mm and relative dielectric constant $\epsilon_r=4.4$). The 50Ω CPW-fed ($f_m \times W_f$) is used for impedance matching. It is calculated using equation (2) and (3).

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \frac{h}{w}}} \right) \quad (2)$$

$$Z_o = \frac{120\pi}{\sqrt{\epsilon_{eff} \left[\frac{w}{h} + 1.393 + 0.667 \ln \left(\frac{w}{h} + 1.444 \right) \right]}} \quad \text{for } \frac{w}{h} \geq 1 \quad (3)$$

The antenna is having overall size of $W \times L$ ($44 \times 44 \text{ mm}^2$). In front surface of the substrate consists circular inner conductor, circular aperture, feed-line, and ground plane. Radius of the circular aperture (Ground size) of the antenna is $R=17.2$ mm, gap between the ground and microstrip line is $g=0.5$ mm. In proposed geometry seventeen different radius inner circle is obtained. The circle radius are

$R_1 > R_2 > R_3 > R_4 > R_5 > R_6 > R_7 > R_8 > R_9 > R_{10} > R_{11} > R_{12} > R_{13} > R_{14} > R_{15} > R_{16} > R_{17}$ is shown in fig. 2. The values of total seventeen circles are $R_1=7.59\text{mm}$, $R_2=6.92\text{mm}$, $R_3=5.7\text{mm}$, $R_4=4.56\text{mm}$, $R_5=3.49\text{mm}$, $R_6=3.23\text{mm}$, $R_7=2.31\text{mm}$, $R_8=2.2\text{mm}$, $R_9=1.5\text{mm}$, $R_{10}=1.3\text{mm}$, $R_{11}=1.25\text{mm}$, $R_{12}=1.21\text{mm}$, $R_{13}=1.2\text{mm}$, $R_{14}=1.1\text{mm}$, $R_{15}=1\text{mm}$, $R_{16}=0.9\text{mm}$, $R_{17}=0.8\text{mm}$. Fig. 3 shows the design steps and its simulated return loss characteristic for different iterations. It is observed that the value of impedance bandwidth and resonant frequency is decreases with increase the number of circle in the geometry. At the final stage it is set to be a dual wideband (2.5/5.2 GHz) application.

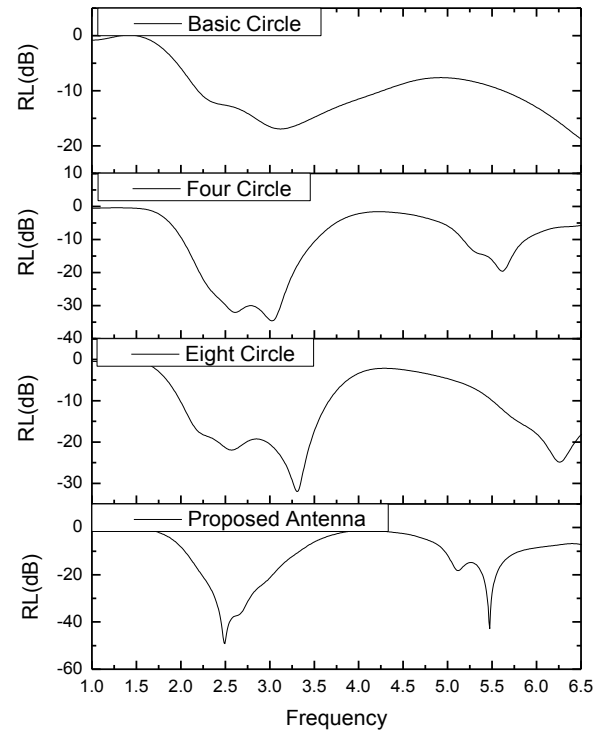


Fig.2 Geometry of proposed circle Fractal Antenna

3. RESULT AND DISCUSSION

3.1 Return loss characteristics

Fig. 3 shows the return loss characteristics of modified irregular circles fractal slot antenna for dual wideband application. The design of the antenna was performed and optimized using CST Microwave Studio Suit™ 2010 based on the three dimensional finite integration time-domains (FITD) method. Proposed antenna is resonating at two frequencies. For first frequency 2.4 GHz (WLAN 802.11 b/g) -10 dB impedance bandwidth from 2.04 to 3.35 GHz and for the second frequency 5.9 GHz for 5.2 GHz (WLAN 802.11 a) -10 dB impedance bandwidth is from 4.96 to 5.9 GHz.

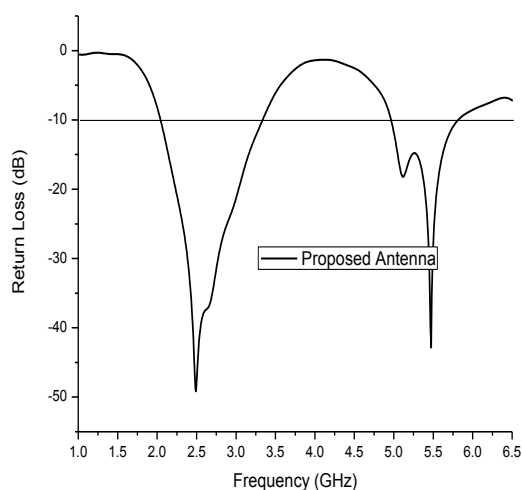


Fig.3 Return Loss of proposed circle Fractal Antenna

3.2 Radiation Pattern Characteristics

The radiation patterns of modified irregular fractal antenna are shown in Fig. 4. The radiation pattern is Omni-directional characteristics. The main cuts E plane at $\phi=0^\circ$ and $\phi=90^\circ$ of proposed fractal antenna are simulated at the frequencies 2.4 GHz and 5.2 GHz. The 3 dB beam width at these two frequencies are 81.9° and 82.3° .

3.3 Surface Current Distribution

The total surface current distribution of proposed modified irregular circle fractal slot antenna at frequencies 2.4 GHz and 5.2 GHz are shown in Fig. 5. The surface current density spreads over the whole patch (up to end of antenna). It radiates strongly at desired WLAN and shows the EM characteristics of proposed antenna.

3.4 Gain

When the antenna is used for wideband application frequency, the impedance mismatch must be taken in to account for defining its characteristics. Especially, while calculating gain of the antenna. Fig. 5 shows the gain of the propose antenna at dual wideband (WLAN) application. it is observed that at 2.4 GHz gain of the antenna is 3.606 dBi and in the range of 5.2 GHz gain is 5.96 dBi.

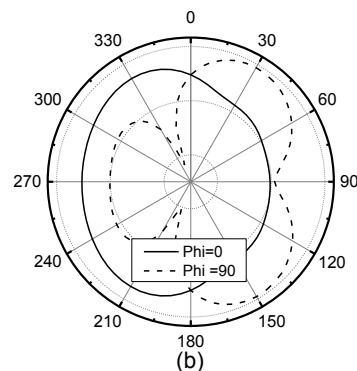
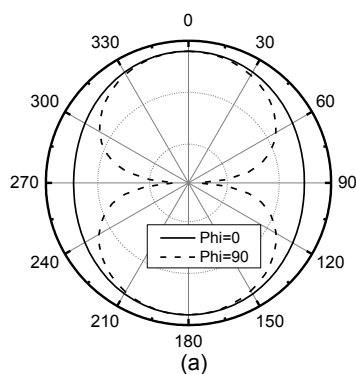


Fig.4 Radiation of proposed circle Fractal Antenna (a) 2.4 GHz (b) 5.2 GHz

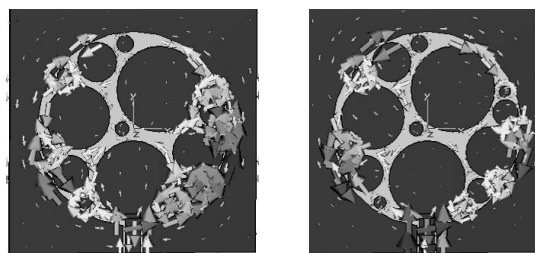


Fig.5 Surface Current Distribution (a) 2.4 GHz (b) 5.2 GHz

4. CONCLUSION

This study proposes an alternative dual wideband approach to obtain a CPW-fed slot antenna with irregular circular fractal geometry. The effects of the various iterative irregular circles parameters on the Antenna performance are studied. Simulated results show the antenna is suitable for the WLAN 2.4/5.2 GHz in *IEEE standard 802.11 b/g and 802.11 a*. the radiation characteristics shows the omnidirectional pattern at E-field and gain of the antenna is 3.606 dBi in the range of 2.4 GHz 5.96 dBi in the range of 5.2 GHz. The EM characteristics is defined by simulated surface current distribution.

5. REFERENCES

- [1] KUO Y.-L., WONG K.-L.: 'Printed double-T monopole antenna for 2.4/5.2 GHz dual band WLAN operations', *IEEE Trans. Antennas Propag.*, 2003, 51, (9), pp. 2187–2192)
- [2] LIN C.C., LEE G.Y., WONG K.L.: 'Surface mount dual loop antenna for 2.4/5 GHz WLAN operations', *Electr. Lett.*, 2003, 39, pp. 1302–1304
- [3] NASHAAT D., ELSADEK H.A., GHALI H.: 'Dual band reduced size PIFA antenna with U-slot for blue tooth and WLAN operations'. *Proc. IEEE Antennas and Propagation Society International symposium, USA, 2003, vol. 2, pp. 962–965*
- [4] SUH Y.H., CHANG K.: 'Low cost microstrip fed dual frequency printed dipole antenna for wireless communications', *Electr. Lett.*, 2000, 36, pp. 1177–1179
- [5] SU C.M., CHEN H.T., WONG K.L.: 'Printed dual band dipole antenna with U-slot arms for 2.4/5.2 GHz WLAN operation', *Electr. Lett.*, 2004, 38, pp. 1308–1309

- [6] Yang, F. , et al., “wide band E-shaped patch antenna for wireless communication”, *IEEE trans. Antennas Propag.*, Vol. 49, 1094-1100, 2001
- [7] WU J.W., HSIAO H.M., LU J.H., CHANG S.H.: ‘Dual broad band design of rectangular slot antenna for 2.4 and 5 GHz wireless’, *IEE Electron. Lett.*, 2004, 40, (23), pp. 1461–1463
- [8] ZHANG Z., ISKANDER M.F., LANGER J.C., MATHEWS J.: ‘Dual-band WLAN dipole antenna using an internal matching circuit’, *IEEE Trans. Antennas Propag.*, 2005, 53, (5), pp. 1813–1818
- [9] Werner D.H., Mittra R., “Frontier of electromagnetic”, (Wiley-IEEE Press, Newyork, 1999)
- [10] H.Jones, , et al., “Fractals and chaos”, A.J.Crilly, R.A.Earnsshaw, and H.Jones, Eds. Newyork: Springer-Verleg, 1990.
- [11] B.B.Mandelbort, “ The fractal geometry of nature” San Francisco, C A: Freeman, 1983
- [12] H.O.Peitgen., et al., “ Chaos and Fractals”, Newyork: springer-Verlag, 1990.
- [13] Dau-chyrh Cang, Bing-Hao Zeng, Ji-Chyun liu, “CPW-Fed circular fractal slot antenna design for Dual-band Application”, *IEEE Trans on antenna and prog.*, Vol. 56. No. 12, Dsec 2008
- [14] J. C. Liu, D. C. Lou, C. Y. Liu, C. Y. Wu, and T. W. Soong, “Precise determinations of the CPW-fed circular fractal slot antenna,” *Microw. Opt. Technol. Lett.*, vol. 48, no. 8, pp. 1586–1592, Aug. 2006.
- [15] J.C. Lagarias, C.L. Mallows, and A. Wilks, Beyond the Descartes circle theorem, *Amer Math* 109 (2002), 338–361.
- [16] S.-W. Qu, C. Ruan, and B.-Z. Wang, “Bandwidth enhancement of wide-slot antenna fed by CPW and microstrip line,” *IEEE Antennas Wireless Propag. Lett.*, vol. 5, pp. 15–17, 2006.
- [17] E. S. Angelopoulos, A. Z. Anastopoulos, D. I. Kaklamani, A. A. Alexandridis, F. Lazarakis, and K. Dangakis, “Circular and elliptical CPW-Fed slot and microstrip-fed antennas for ultrawide-band applications,” *IEEE Antennas Wireless Propag. Lett.*, vol. 5, pp. 294–297, 2006.
- [18] Y.-C. Lin and K.-J. Hung, “Compact ultrawide-band rectangular aperture antenna and band-Notched designs,” *IEEE Trans. Antennas Propag.*, vol. 54, no. 11, pp. 3075–3081, Nov. 2006.
- [19] P. Li, J. Liang, and X. Chen, “Study of printed elliptical/circular slot antennas for ultrawide-band applications,” *IEEE Trans. Antennas Propag.*, vol. 54, no. 6, pp. 1670-1675, Jun. 2006.