International Journal of Natural and Engineering Sciences 7 (2): 13-16, 2013
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Ultra wideband multi-segment fractal antenna with circular polarization for WLAN-WiMAX applications

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Received: September 13, 2012

Accepted: October 19, 2012

Abstract

A new design microstrip-fed ultra-wide band (UWB) printed multi-segment circular fractal antenna with circular polarization for WLAN/WiMAX applications is presented. The proposed antenna comprised of a half ellipse ground plane, a fractal patch and I-shaped stub which usable circular polarization for WLAN/WiMAX frequency bands. By embedding a I-shaped stub in the ground plane, impedance and axial ratio bandwidth will be increased. The proposed fractal antenna has a small size of 25x25x1 mm^3 and operates over the frequency band between 2.68 and 11.6 GHz with VSWR < 2. A prototype of the UWB fractal antenna has been implemented and the S11 and axial ratio results have been compared with the measured values.

Keywords: fractal antenna, UWB, Circular polarization.

INTRODUCTION

In last decades, the rapid development of wireless communication systems has urged the need for dual band, multiband and UWB antennas [1-8]. Between all kinds of planar antennas, circular polarization antennas with better mobility and weather penetration than linear polarization antennas have received much attentions. In recent years, fractal concepts have emerged a new methodology for designing compact UWB, and multiband antennas according to its space filling and self-similarity characteristics of these structures [1-8]. In this letter, a novel circular fractal monopole antenna using multi fractal technique for UWB application is presented. The proposed multi segment circular fractal exhibited very good miniaturization ability due to its self-similar properties [1], [3],[8]. Due to the asymmetric structure of this layout, microstrip feed line position is effects on the proposed antenna performance [2]. Therefore, the feed line position (D) should be optimized for better antenna performance [2],[9,10]. In recent years, different techniques such as cutting different shaped of slots in main patch or ground plane, a fan-shaped patch, ring slot and cross shaped patch has been used to produce circular polarized radiation in printed antennas [7].In general, the printed monopole antenna radiation patterns are linearly polarized (LP) [7]. Therefore, design of circular polarized printed monopole antenna which was generated with two orthogonal modes with 90 degree phase difference (PD) is very difficult. For this reason, in the proposed design a multi-segment fractal structure to excite two orthogonal modes with 90 degree PD with very simple structure is designed. The proposed microstrip fractal antenna is connected to 50-ohm standard SMA connector.

The proposed UWB antenna design and circular polarized operation for WLAN/WiMAX (5150-5350/5725-5825MHz) is presented and discussed in details.

MATERIALS AND METHODS

Multi-segment circular fractal configuration

The proposed circular fractal is a two dimensional (2D) fractal constructed from multi-segment circles. The construction of the proposed fractal begins with an iterative process at odd numbered iterations *km, m=1,3,…,2M+1*, where *M* is a positive integer number. As shown in Fig.1, the proposed fractal initiator is partitioned into three non-overlapping segments with different radius. The same procedure is then applied recursively to the other remaining layer with iterated function transformations, ad infinitum. In the proposed fractal, all the segments angle have $M=2\pi/n$ constant value and different radius $r=R, 2R, \ldots, nR$. Fig.1 shows illustration of the first four iterations in the construction process. The lower band-edge frequency (f_{Ln}) of the proposed multi-segment fractal antenna at the iteration k_n is approximated theoretically as Eq. 1.

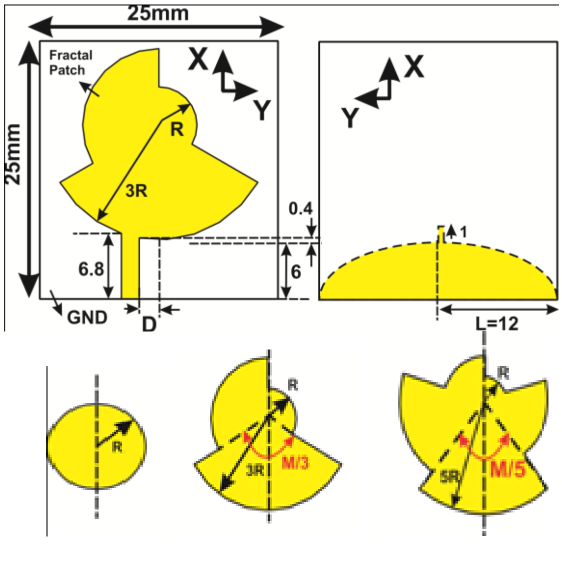
$$f_{Ln} = \frac{c}{\lambda} = \frac{7.2}{(L+r+p)*k_{eff}} GHz \quad (1)$$

Where *r* in *mm* is the effective radius of the equivalent cylindrical antenna, *L* is the height of the planar monopole antenna in mm and the factor k_{eff} has similar significance as. Also, *g* is the gap distance between the semi-ellipse ground plane (GND) and fractal radiating planes which is *0.5mm* in the proposed fractal antenna

Fractal antenna configuration

Fig. 2 depicts the configuration of the fabricated UWB fractal antenna, which consists of multi-segment circular fractal patch, a semi-ellipse shaped ground plane and I-shaped strip. The proposed circular fractal antenna is printed on a commercial FR4 substrate with permittivity of *4.4* and small dimension of $25x25x1mm^3$. The width Wf of the microstrip feed-line is fixed at 1.85 mm to achieve 50-ohm characteristic impedance [1]. The proposed multi-segment circular fractal iterations are shown in Fig.1.

This fractal contains three segments of equal $\theta=2\pi/3$ radian with a difference in the radius. The circular fractal patch has a distance of $g = 0.5$ *mm* to the semi-ellipse ground plane having length of $L_g = 6$ *mm* printed on the back surface of the FR4 substrate. The proposed fractal antenna parameters are simulated using a High Frequency Structure Simulator (HFSS, ver.13). From the parametric studies, we have found that changes in the radius (*R*) of the circular segments, resonant frequency ratios will be change. Also, it is observed that the impedance bandwidth increases as the *R* are increased. The simulation results for the different R values indicates that, as the circular segments radius (*R*) increases from *2.5* to *4.5 mm*, the lower band-edge frequency of the fractal antenna will be decreased. Therefore, for providing good impedance characteristics for this fractal antenna over the application band, the *R* parameter of the proposed fractal choose equal to *4mm*. On the other hand, as *R* increases more than *4 mm*, the lower-edge of operating band is decreased but total antenna size is increased. For this reason to better performance of the proposed antenna, optimized value of *R* parameter is fixed at *4 mm* for compact design. Hence, multi-segment fractal results depicted that the small changes in the width of the gap between the semi-ellipse ground plane and the circular fractal patch (*g*) has a great effect on the impedance matching of the



(a) (b) (c)

Figure 1. (a) Configuration of the proposed fractal antenna (all in mm) and geometry of proposed multi-segment circular fractal iterations: (b) first odd iteration k_1, (c) second odd iteration k_3, and (d) third odd iteration k_5.

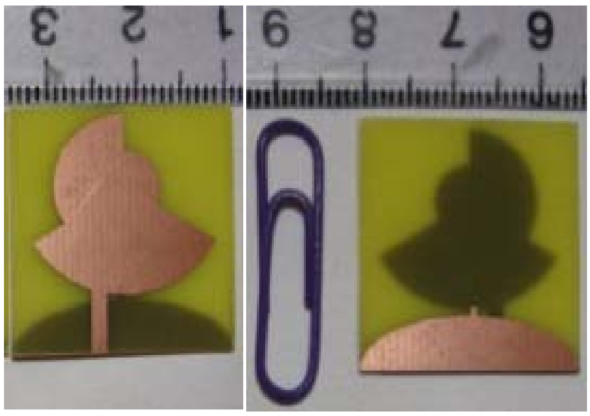
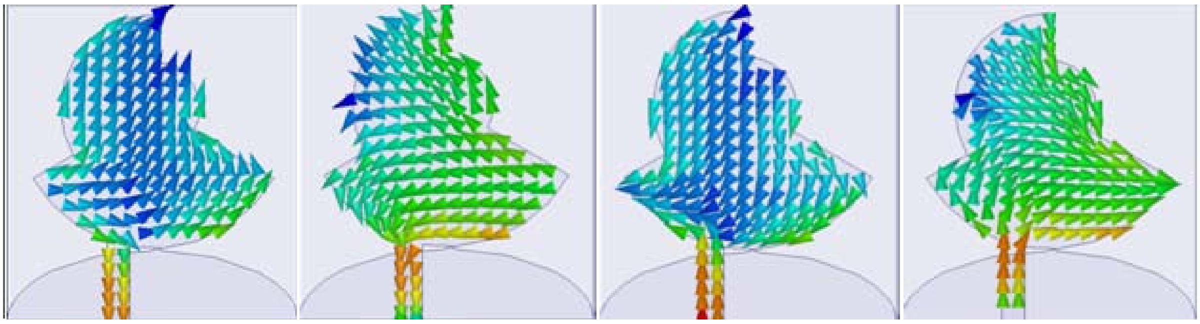


Figure 2. Photograph of the fabricated multi-segment circular fractal antenna.

proposed antenna entire the operating band. By increasing *g* values from *0.3* to *0.5mm*, the lower band-edge frequency decreases from *3.4* to *2.8* GHz. Due to the proposed antenna asymmetrical structure as shown in Fig. 2, the feed line position should be design properly to excite different resonant modes of the antenna [2]. The simulation results for different *D* values in x-axis direction indicates that, by increasing *D* up to 3mm impedance matching over the frequency band is increased and much more resonances is produced.

The general radiation properties of conventional monopole antenna are either horizontal or linearly polarized (LP). If the conventional monopole antenna is vertically LP, the radiation in the horizontal direction is very weak [2]. For this reason, in the conventional monopole antenna structure comprised of a main patch and ground plane without any changes to circular polarized behavior, generation of two orthogonal *E* vectors (E_{Hot}, E_{Ver}) with equal amplitude and 90° phase difference (PD) to excite circular polarized radiation is very difficult. The proposed multi-segment



(a) (b) (c) (d)

Figure 3. Distribution of the surface current on the feed and fractal patch of the CPSS antenna at 5.45 GHz in a:0phase ,b:90 phase ,c: 180 phase ,d: 270 phase.

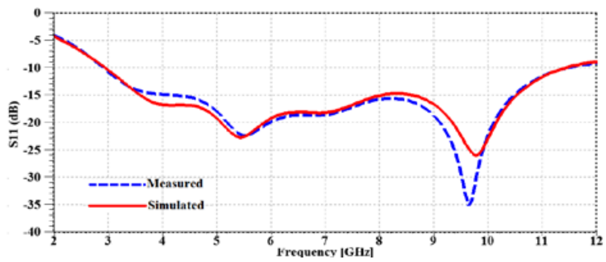
circular fractal antenna with added I-shaped stub (with L_3=*1mm* length and *0.6mm* width) to the ground plane has a circular polarized characteristics with AR<3 from *4.96* to *5.78* GHz. The simulation results for different L_3 values in x-axis direction indicates that, by increasing L_3 up to 1mm impedance matching over the frequency band is increased and much wider axial ratio bandwidth is produced.

In the proposed structure combination of three different radiuses circular segments as a main patch (Fractal patch) excite two orthogonal modes to produce circular polarization. Between different techniques presented in recent years, a I-shaped stub are added in the semi-ellipse GND to further enhance the axial ratio (AR)- and impedance-bandwidth of the proposed circular fractal antenna. The position of the I-shaped stub added to the ground plane can interfere with the antenna performance. If the I-shaped are moved to the Y-axis direction (left side) as shown in Fig. 1(a), both axial ratio- and impedance-bandwidth of the proposed antenna will be destroyed. For this reason, microstrip feed line and I-shaped stub positions in this layout should be located in opposite direction.

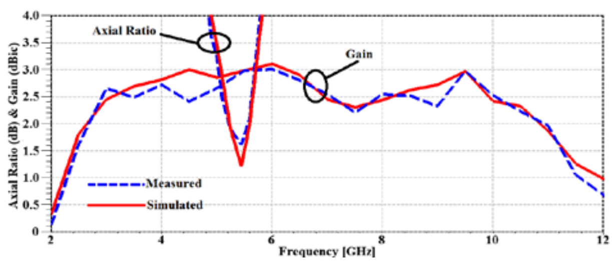
RESULTS AND DISCUSSIONS

The proposed multi-segment fractal antenna is manufactured at the second odd iteration k_3 with $R = 4$ *mm*, $D=-3$*mm*, L_3=*1mm* and g=*0.4mm* using the cheap FR4 substrate, as shown in Fig. 2. We simulate the time-varying surface current distribution on Antenna at *5.45* GHz, the minimum point of AR. The simulation results of surface current distribution for Antenna are shown in Fig. 3. It is observed that the surface current distribution in *180* and *270* are equal in magnitude and opposite in phase of *0* and *90*. If the current rotates in the clockwise (CW) direction, the antenna can radiate the right-hand circular polarization (RHCP). The proposed circular polarized fractal structure makes proposed antenna more flexible to design desired operating band width.

Another main parameters of the proposed fractal antenna is the width of the gap between the fractal patch and the GND. The simulation antenna results are obtained using the Agilent8722ES network analyzer. The measured and simulated S11 and axial ratio results of the proposed fractal antenna are in good agreement with each other. The measured impedance bandwidth has an operating frequency range from 2.68 to 11.6 GHz as shown in Fig.4(a). The simulated and measured fractional circular polarized BWs of 4885-5823 GHz and 4987-5782 MHz, respectively, agree well with each other. Fig. 5 shows the measured normalized right hand-(RHCP) and left hand-circular polarized (LHCP) radiation pattern of the proposed fractal antenna at 5.45 GHz, the minimum point of the corresponding 3dB axial ratio bandwidth as shown in Fig.4 (b).The maximum antenna gain is 3.1 dBic at 6 GHz. The antenna gain is change between 2.1- and 3.1-dBic over the operating band.



(a)



(b)

Figure 4. (a) Comparison between measured and simulated S_{11}, (b) Comparison between measured and simulated axial ratio and gain results of the proposed multi-segment circular fractal antenna.

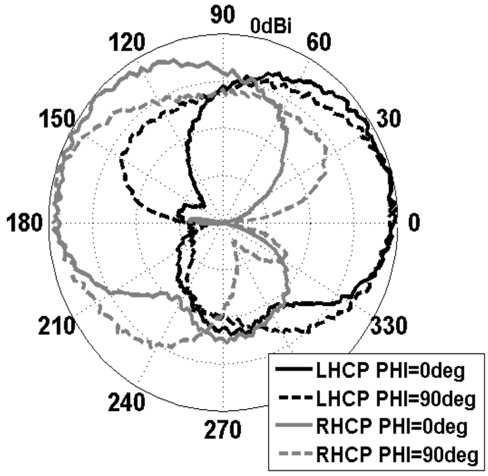


Figure 5. Measured normalized RHCP and LHCP radiation patterns results of the proposed fractal antenna at 5.45GHz (φ=0º and 90º).

CONCLUSION

A novel multi circular fractal monopole planar antenna with a very compact size was presented and investigated. The operating bandwidth of the proposed multi circular antennas covers the entire frequency band from 2.68-11.6 GHz. The antenna gain is nearly flat over the operating frequencies. Both measured and simulated results suggest that the proposed multi circular antenna is suitable for UWB communication applications with circular polarized for WLAN/WiMAX applications.

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