International Journal of Natural and Engineering Sciences 8 (2): 10-14, 2014
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

A Novel Printed Monopole Antenna with a Combination of Koch and Giusepe Peano Fractals Structure Fed by Modified CPW for SWB Applications

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Received: May 03, 2014
Accepted: June 11, 2014

Abstract

In this letter, a novel printed CPW-fed fractal monopole antenna is presented for super-wideband (SWB) applications. The proposed antenna is composed of this combination: the first iteration of half Giusepe Peano fractal and Koch fractal,which is applied on circular patch. To achieve impedance matching, the feed circuit is designed by a modified CPW line with a semi-circular ground plane. The presented antenna has the compact size of $40\times45\times0.51$ $mm^3$and operates over the frequency band ranging from 1 to 25 GHz with bandwidth ratio 25:1 for VSWR<2.The design process of the proposed structure to improve the impedance bandwidth and computed results from simulation and measurement have been presented and compared. The measurement results have a good agreement with simulated ones. This antenna is suitable for UWB and SWB applications and covers most of the communication standards.

Keywords: Fractal,monopole antenna, SWB, CPW-Fed

INTRODUCTION

In the last decade, much effort has been made on the bandwidth enhancement of antenna, being recognized as a critical component of wireless communication systems[1]. Besides exploiting the ultra wideband (UWB) operating band from 3.1 to 10.6 GHz for wireless personal area network (WPAN) applications [2], the current users of WPAN are also eagerly demanding a super wideband (SWB) to cover both short- and long-range transmission for ubiquitous services [6]. However, limited numbers of SWB antennas are reported in the open literature [3]-[5], and the existing UWB antennas are not efficient enough for diversified communication systems [6].

Recently, some antenna with ratio impedance bandwidth of more than 10:1, which are named as super wideband (SWB) antennas in the antenna literature, have been proposed[1], which was classified as a class of frequency-independent antennas[7]. Some kind of monopole antennas using modified patch and ground plane or feeding structure have been considered due to more improvement of the BW [1-6] and radiation characteristics[6-8]. Additively, minimizing the antenna size while keeping the previous features such as wide BW, good matching and stable radiation characteristics is more profitable [8].

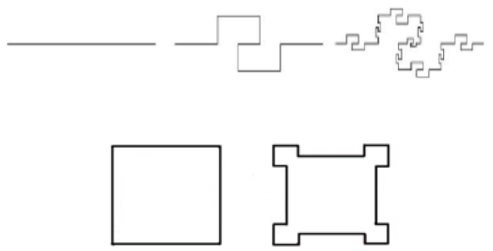
The fractal antennas are preferred because they not only are small and light for easy installation, but also have extreme wideband [12-14]. To support a high mobility necessary for wireless telecommunication devices,small and light antenna characteristics would be likely preferred [9]. Micro-strip antenna is one of the most suitable candidates for this purpose [9]. Applying fractal geometry to Micro-strip patch antenna improves bandwidth and radiation patterns.

In this paper, a fractal monopole antenna is presented for the coverage of operating frequency 1-25 GHz which is introduced by the combination of Giusepe Peano and Koch fractals. The Peano fractal is applied to the circular patch and the Koch fractal is implemented on the patch area.

To achieve a broadband performance from fractal geometries, modified CPW feed configuration is proposed.The antenna consists of wide bandwidth, a good gain, omnidirectional radiation pattern and high efficiency. The design and simulation was performed using commercial lAnsoft Company software High Frequency Structure Simulator (HFSS) ver.13.

ANTENNA DESIGN

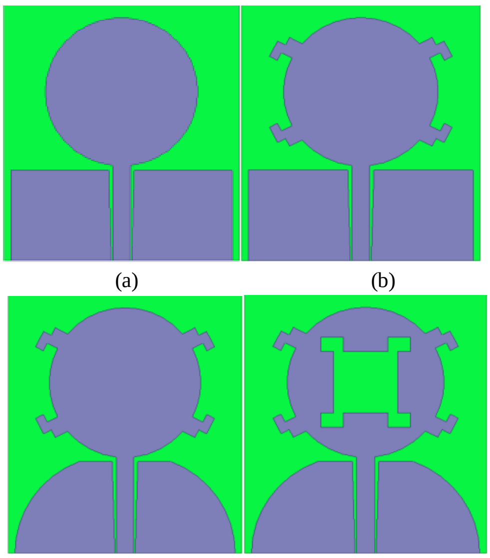
The recursive procedure of the Giusepe Peano fractal [15] and Koch fractal [16] is shown in Figure 1. The procedure of antenna design is shown in Figure 2. The configuration of proposed antenna with optimal values is presented in Figure 3. This geometry composed of applied fractals to circular patch with a semi-circular shape ground plane. It is used for first iteration of Koch fractal and half of first iteration of Giusepe Peano fractal. We used Giusepe Peano fractal structure to modify radiation patterns of circular monopole antenna in high frequencies. As this fractal structure is changing the direction of electrical currents on antenna, which make omnidirectional radiation patterns. This fractal structure at the edge of vicinity of square ground plane is closing to ground plane, their distance is a few hundredths of a wavelength in low frequencies and cause mutual coupling between them,thereby creates return currents in the feed of antenna , so return losses of antenna is increasing. Gradually with increasing electrical distance according to figure 2(c) and figure 4, this effect is decreasing in high frequencies. With cutting circular ground plane in top section near the patch with a small rectangle, the distance between patch and ground planes have increased so their effect on each other is diminished and achieved to better impedance matching.It is noticed that Koch fractal effect after first iteration is more inconsiderable also because of manufacture limitations, and are just used for first iteration of two fractals.



(a)

(b)

Figure 1. a) Initiator and generator of Giusepe Peano fractal. b) Initiator and generator of Koch fractal



(a) (b)

(c) (d)

Figure 2 . Procedure of antenna design

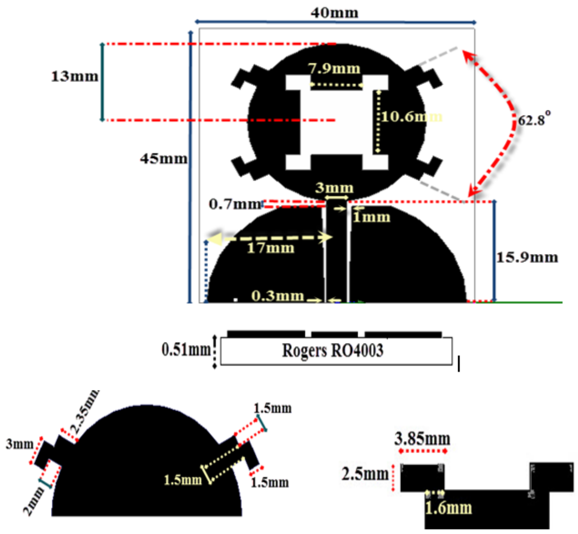


Figure 3. Configuration of fractal monopole antenna

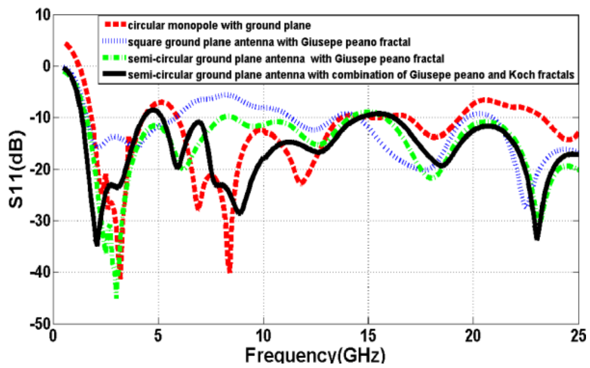


Figure 4. Return losses for design process

Printed antennas are attractive because of their planar geometry and wide operating bands [10]. A coplanar waveguide (CPW) feed makes it more suitable for compact wireless communication devices owing to its features like uniplanar structure, easy fabrication and circuit integration [11]. The printed antenna with the dimension of 40×45 mm² is supported by a 0.51mm thick Rogers RO4003C substrate with ε_r=3.55 and tanδ =0.0027.To achieve a better impedance matching that cause bandwidth enhancement, with CPW line made as an impedance transformer. The width gap between CPW central strip and ground planes at top end is g=1mm, corresponding to a characteristic impedance of 100Ω, and the width gap at the bottom end is g =0.3 mm, corresponding to a characteristic impedance of 50Ω. The CPW line from end to joint point to patch gradually transforms the impedance from 50Ω to 100Ω.

SIMULATED & EXPERIMENTAL RESULTS

The proposed antenna is fabricated and measured (Fig5). It must be mentioned that just for survey fractal geometries effect on antenna performance, the proposed antenna is investigated in 3 steps.

1) Antenna without fractal (circular patch)
2) Antenna with Giusepe Peano fractal

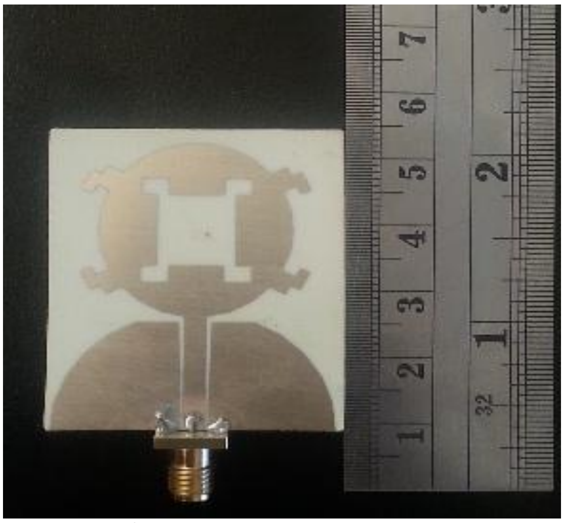
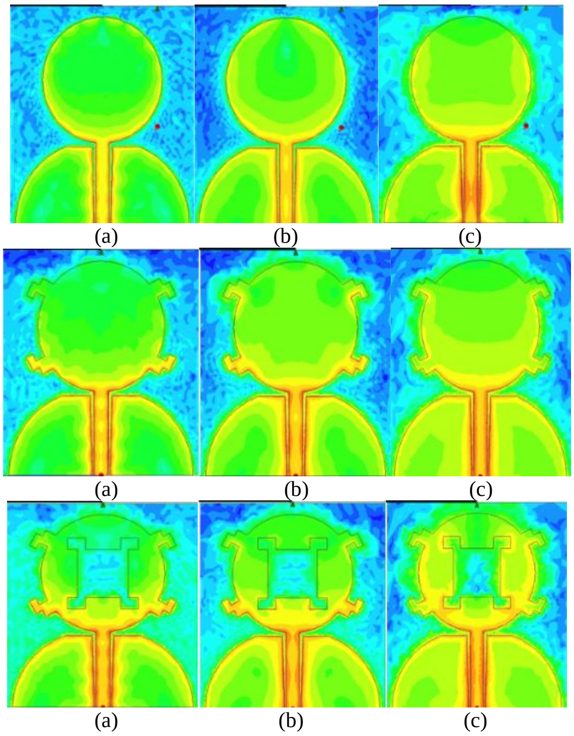


Figure 5. The fabricated prototype

3) Antenna with Giusepe Peano fractal and Koch fractal

Current distributions for 3 steps are shown in figure 6. Observe that in step 1 with increasing frequency, electric currents concentrate on edge of ground planes near to strip line and the bottom part of patch, in the last step (combination fractals), it is seen in 25GHz electric currents distribute on circular patch and around fractals. Combination structure improves current distribution situation on circular patch so most parts of antenna take apart in radiation. The comparison of radiation patterns of the proposed antenna in 3 step shown radiation patterns are improved.



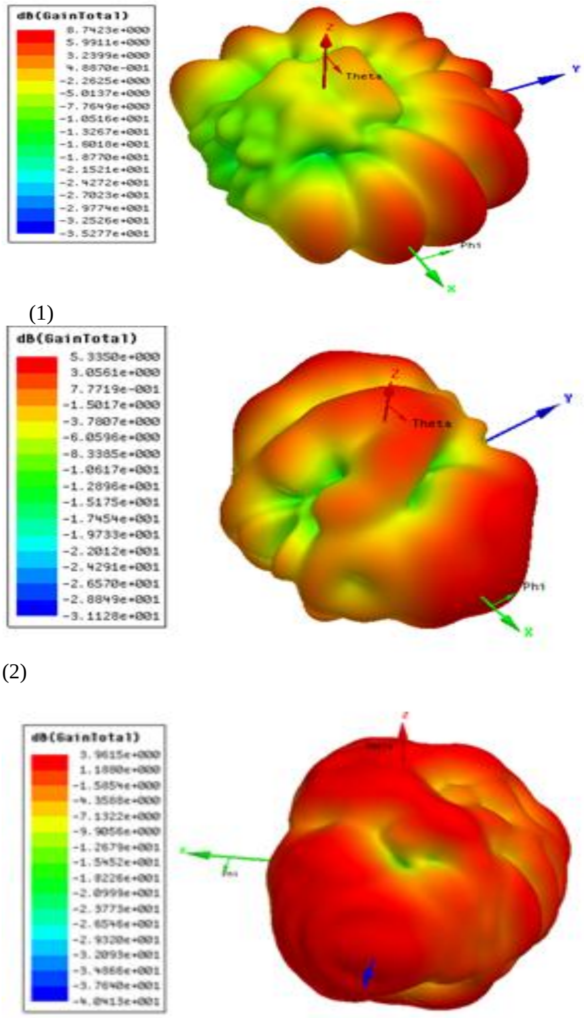
(a) (b) (c)

(a) (b) (c)

(a) (b) (c)

Figure 6 Current distributions for 3 steps in a) 3 GHZ, b) 12 GHz, c) 25 GHz

According to figure 7, in the first step, radiation patterns in high frequencies, for instance in 25GHz, are like Endfire patterns. In the second step, patterns is almost improved to omnidirectional, but S11 is increased(>-10dB) in the section of antenna's feed. In the third step, it is seen that we have achieved an antenna with good omnidirectional radiation patterns and return loss(<-10 dB) frequency ranging 1-25 GHz. In figure 4, return losses for 3 steps is shown. After applying Koch fractal, the first frequency resonance shift to lower frequencies is seen in step 3, so bandwidth is increasing.



(1)

(2)

(3)

Figure 7. 3D gain total radiation pattern in 25GHz for 3 steps

To provide a reasonable comparison between two wideband antenna (especially UWB antenna), the authors have used an index term that will allow antenna engineers to identify if their planar antenna design (compared against the other design) is very much compact in size and wide in bandwidth [6]. Here, to determine both the compactness and wideband characteristics of a planar antenna, we use this index term which is named the bandwidth dimension ratio (BDR). This index term will indicate how much operating bandwidth (in percentage) can be provided per electrical area unit (unit: $\%/\lambda^2$) [6]. The equation is written as following [6]:

$$\mathrm{BDR} = \frac{BW\%}{(\lambda_{length} \times \lambda_{width})} \quad (1)$$

Where λ is the wavelength of the lower-edge frequency of the band that meets the 10-dB return loss. Here, a larger BDR will indicate that the design antenna is smaller in dimension and wider in bandwidth [6]. The comparison between the proposed antenna and other designed antennas are presented in Table 1.The simulation and measurement results for S11 are shown in Fig 8. The VSWR,radiation efficiency andgain versus frequency are shown in Fig 9 and Fig10. Observe that proposed antenna has almost constant VSWR below 2 and peak gain of 6.15dB in 23GHz. The measured radiation patterns are illustratedin Fig11 for three frequencies of 2, 10, 18 GHz in E-plane and H-plane.

The 10-dB bandwidth of proposed antenna is 185% and a ratio band of 25:1 and high BDR, so this antenna has extreme wideband to its dimension.

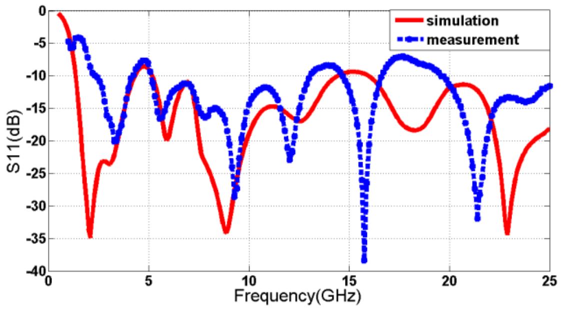


Figure 8. Simulation and measurement results for S11

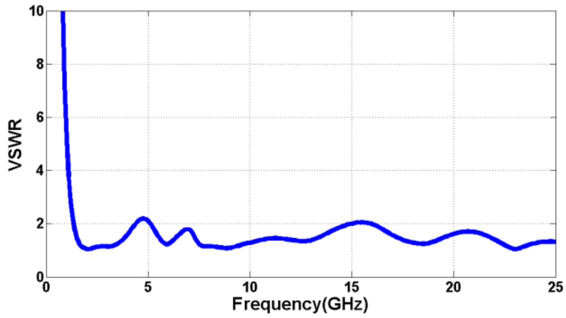


Figure 9.VSWR of proposed antenna

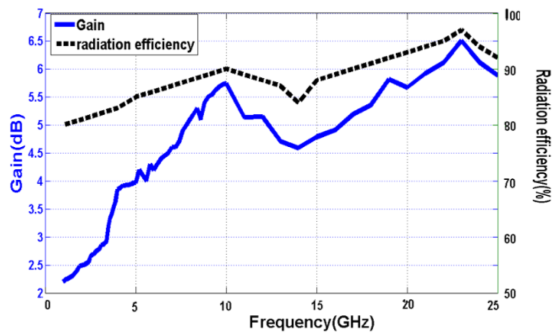


Figure 10. Simulated results of gain and radiation efficiency of proposed antenna

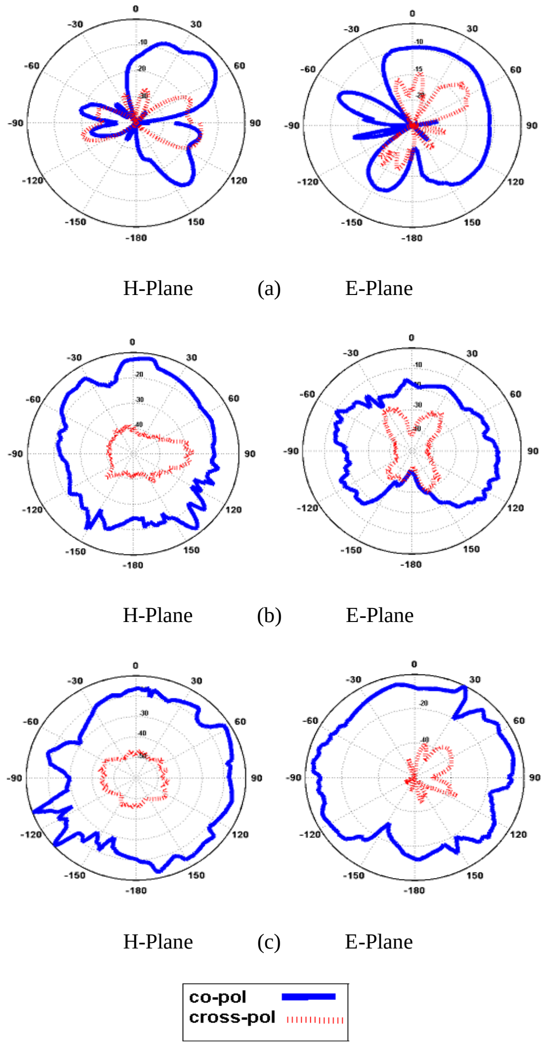


Figure 11. Measured radiation patterns of the proposed fractal antenna for E-plane and H-plane in a) 2GHz. b)10GHz. c)18GHz.

CONCLUSION

A novel printed fractal monopole antenna with a ratio bandwidth greater than 25:1 has been introduced. The proposed design is composed of the combination of two fractals. We are investigated fractal effects on antenna performance to improve antenna characteristics. It is shown that proposed antenna has wide bandwidth more than 185% in range of frequency 1-25 GHz, compact size, low profile, omnidirectional pattern and high gain. We discussed about BDR index and showed that the proposed antenna has compact size to its extreme bandwidth. The proposed antenna can be useful in UWB and SWB applications as well as suitable for various military, commercial and medical equipments.

Table 1. Comparison between several antennas for SWB applications

Antenna	10-dB BW (%)	Size/λ^2	Ratio BW (VSWR≤2)	BDR	F_{low} (GHz)
[1]	192	0.21× 0.16	47:1	5714	0.52
[17]	167	0.37× 0.24	21.25:1	1876	0.79
[18]	175	0.38 ×0.38	15.38:1	1250	1.30
[4]	185	0.32×0.34	25:1	1682	0.64
proposed	185	0.13×0.15	25:1	9273	1.00

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