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A novel small triple-band monopole antenna with crinkle fractal-structure

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ABSTRACT

A novel monopole antenna with crinkle fractal-structure for multiband applications is presented. In this paper adding crinkle fractal leads to increasing the number of resonance frequency. The operating frequencies of the proposed antenna are 1.780/3.520/5.260 GHz. The prototype of the proposed antenna is fabricated on an inexpensive FR-4 substrate. The size of the proposed antenna is $14 \times 14\ mm^2$ which has crinkle shape strip on top side. The radiation pattern of the proposed antenna is nearly omnidirectional. The simulated and the experimental results are in acceptable agreement with each other and confirm good performance for the offered antenna.

1. Introduction

Recently, the need for the design of an antenna with multiband operation has increased. The engineering new challenges in wireless communication systems include small-size, easy fabrication, low–cost, light weight, high-performance, and wide bandwidth antenna. Microstrip monopole antenna has wide impedance bandwidth, small size, light weight and it is good candidate for multiband operations [1–4]. The multiband antennas have main role for wireless local area network (WLAN: 2.4–2.484, 5.15–5.35 and 5.725–5.85 GHz) and worldwide interoperability for microwave access (WiMAX: 2.5–2.69, 3.4–3.69 and 5.25–5.85 GHz) applications. The speedy growth in wireless communication systems, caused multiband antenna more stand beloved [5,6]. A compact antenna with a straight coupled-fed microstrip line, U-shaped slot for multi-band applications is presented. This antenna has good radiation and gain characteristics, and can cover Digital Communication System [7]. In [8], a penta-band antenna for mobile phone applications is presented. The antenna has two modified inverted-L patch and short grounded transmission line for impedance matching. There have been different antennas for DCS application [1–4,7–10]. A compact coplanar waveguide (CPW)-fed antenna for WLAN/WiMAX applications is presented. The radiation patch is fed by transmission line and with using parasitic strip on the back plane of the substrate, tri-band resonances are generated [11]. In [12], a novel monopole antenna by microstrip-fed for WLAN/WiMAX applications is presented. The proposed antenna consists of one branch strip, two hook-shaped strips and a rectangular slot in the ground plane. A novel dipole antenna with multiband operation for WLAN/WiMAX applications is presented. The antenna consists of several symmetrical branch strips and modified rectangular ground plane, a modified rectangular plane is act as a reflector for directive gain [13]. In [17], the antenna consists of L-shaped slits and an inverted L-shaped slot in the radiating patch for WLAN/WiMAX applications is presented. There has been different antenna for WLAN/WiMAX applications [5–6,11–21]. In [18], a coplanar waveguide-fed (CPW) antenna includes a square spiral patch to increase resonance frequencies and two L-shaped strips for achieving wider impedance bandwidth. The antenna can cover 2.4/5.2/5.8 GHz WLAN and 3.5/5.5 GHz WiMAX bands. In [19], a microstrip antenna consists of two square spiral arms presented. The antenna by using square spirals, can achieve multiband operation for WLAN/WiMAX applications.

In this essay a novel monopole antenna with crinkle fractal-structure for DCS/WiMAX and WLAN applications has been reported. The antenna include of crinkle fractal radiating structure, which this crinkles achieve by parametric simulations. By adding crinkle fractal the number of resonance frequencies are increased. The proposed antenna has wide impedance bandwidth. The

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antenna has a easy structure and small size, the measured results show impedance bandwidths of 189 MHz (1.691–1.880 GHz), 212 MHz (3.412–3.624 GHz), 302 MHz (5.139–5.441 GHz), to cover the DCS or GSM1800: 1.795 GHz, worldwide interoperability for microwave access (WiMAX: 3.5 GHz), wireless local area network (WLAN: 5.2 GHz), and good radiation characteristics for the operating bands.

2. Antenna design

Fig. 1 shows geometrical configuration of the suggested antenna which is printed on an FR4 substrate with a size of 14(x-axis) × 14 (y-axis) × 1 mm^3, relative permittivity of 4.4, and loss tangent of 0.022. The crinkle fractal as radiating element and 50 Ω microstrip line with fixed width W_F and length L_F, are used on the top side of the substrate. The partial ground plane with constant width of L_G = 4 mm is embedded on the other side of substrate. By adding crinkle fractal the number of resonance frequencies are increased. The monopole antenna with different design parameters was manufactured, and the simulated and measured results of the input impedance and radiation characteristics are introduced and argued. The simulation results are earned using Ansoft High-Frequency Structure Simulator (HFSS) [22]. The ultimate dimensions of the proposed antenna are defined in Table 1.

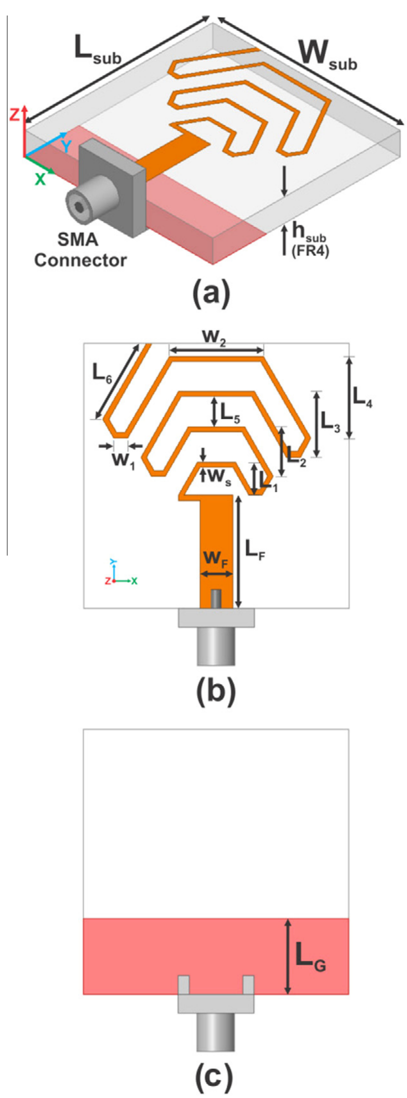

Fig. 1. Geometry of the proposed antenna, (a) side view, (b) top view, (c) bottom view.

Table 1
The ultimate dimensions of the proposed antenna.

Param.	mm	Param.	mm	Param.	mm
L_F	6	L_1	2	L_2	3
L_3	4	L_4	5	L_5	1.6
L_6	4.6	L_G	4	W_1	0.7
W_2	5	W_F	1.7	W_s	0.3
W_{sub}	14	L_{sub}	14	h_{sub}	1

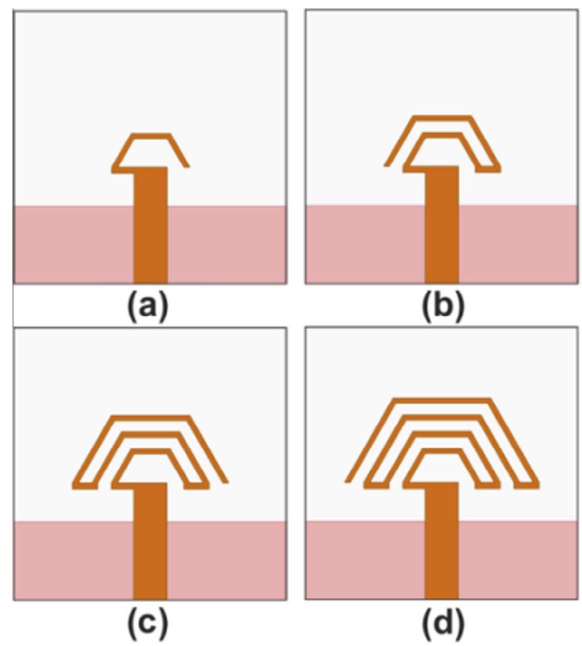

Fig. 2. (a) The ordinary antenna. (b) The antenna with adding first fractal. (c) The antenna with adding second fractal. (d) The proposed antenna.

The design procedure for the proposed antenna is shown in Fig. 2. Fig. 3 shows the return losses for the ordinary antenna in (Fig. 2(a)), the antenna with adding first fractal in (Fig. 2(b)), the antenna with adding second fractal in (Fig. 2(c)) and the proposed antenna in (Fig. 2(d)). In this case, the new coupling paths between square spirals and ground plane can be obtained and thus the number of resonance frequencies are increased.

Return loss characteristics in Fig. 3, show that the ordinary antenna to cover the frequency-band (7.581–7.906 GHz), for the antenna with adding first fractal frequency resonance ranges are (4.053–4.269 GHz) and (7.542–8.073 GHz), the antenna with second fractal frequency resonance ranges cover (2.644–2.931 GHz), (5.176–5.317 GHz), and (7.332–7.707 GHz) and the proposed antenna can cover (1.988–2.195 GHz), (3.659–3.811 GHz), (5.171–5.392 GHz), (6.782–7.046 GHz), and (9.456–9.691 GHz). The return loss characteristics show that by adding crinkle fractal the number of resonance frequencies are increased. By increasing the number of resonance frequencies the proposed antenna can be used for UMTS, WiMAX and WLAN applications. The parametric studies for proposed antenna are illustrated in Figs. 4 and 5. Fig. 4, shows return loss characteristics for the proposed antenna with various L_2. Return loss characteristics with various values of L_2 show narrow bandwidth specially at the middle frequency ranges

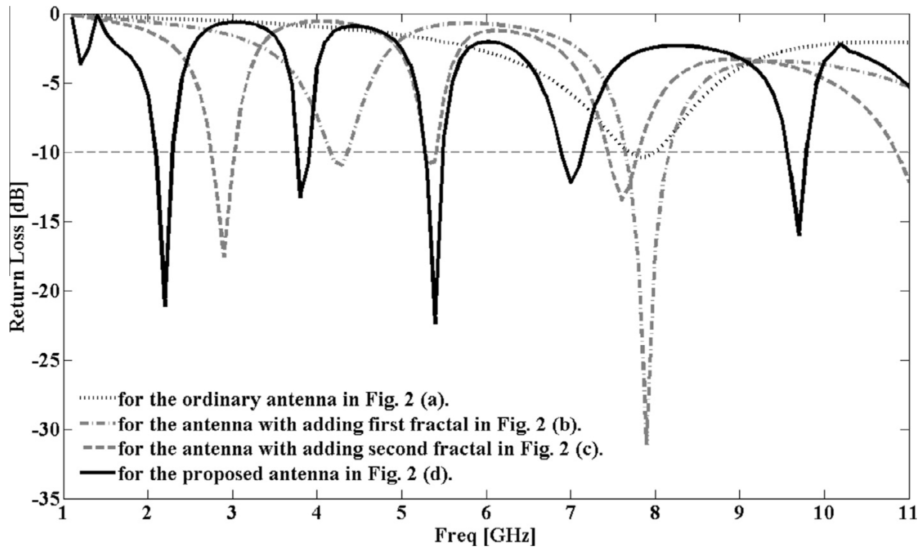

Fig. 3. Simulated return loss characteristics for antennas shown in Fig. 2(a)–(d).

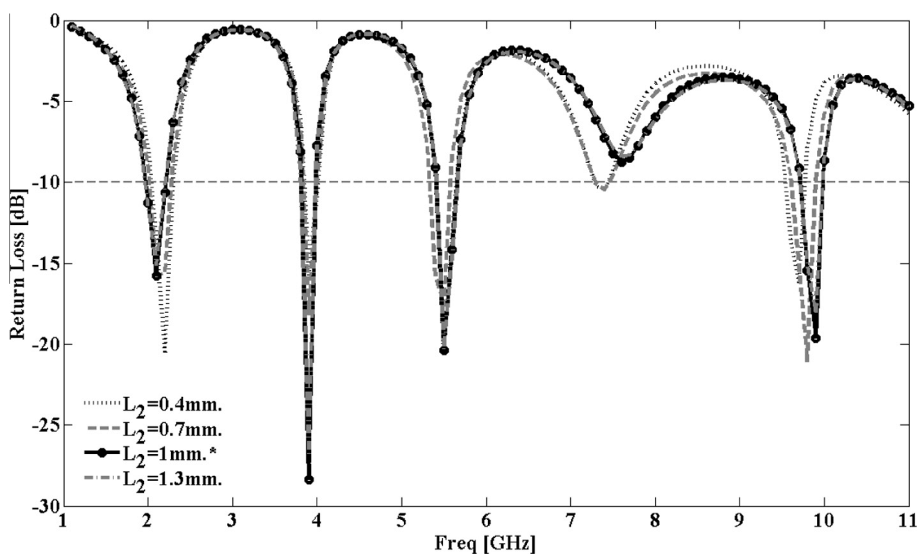

Fig. 4. Simulated return loss characteristics for the proposed antenna with respect to different values of L_2.

and have a great effect on moving resonant frequency to higher frequency ranges. In Fig. 5, return loss characteristic with various values of L_4 are shown. The resonance frequencies can be controlled by different values of L_4 especially at the middle and higher frequency ranges. The process of increasing the resonance frequencies for the proposed antenna is summarized in the Table 2.

For more clarification of the frequency performance of the crinkle fractal, current distributions for the monopole antenna is shown in Fig. 6. According to this figure, for the proposed antenna at the frequency at 2 GHz the currents, which flow around first, second and third fractal Fig. 6(a), are more active. Also at 3.7 GHz the currents flow approximately to the right side of the fractal Fig. 6(b), are more active. Furthermore, as seen in Fig. 6(c), surface currents at the frequency of 5.2 GHz are nearly equal around all crinkle fractal. Therefore, multiband operation can be achieved by different radiated parts of square spirals.

3. Results and discussion

The proposed antenna with the ultimate design parameters as shown in Fig. 7. The measured and simulated return loss characteristics of the proposed antenna are shown in Fig. 8. A suitable adaptation between the simulated and measured characteristics can be seen in Fig. 8. The measured results show impedance bandwidths of 189 MHz (1.691–1.880 GHz) with center frequency resonance 1.78 GHz, 212 MHz (3.412–3.624 GHz) with center frequency resonance 3.52 GHz, and 302 MHz (5.139–5.441 GHz) with center frequency resonance 5.26 GHz, to cover the (DCS or GSM1800: 1.795 GHz), worldwide interoperability for microwave access (WiMAX: 3.5 GHz), wireless local area network (WLAN: 5.2 GHz), with suitable reflection coefficient under −10 dB. The normalized radiation patterns containing co-polarization and cross-polarization in the H-plane (x-z plane) and E-plane (y-z plane)

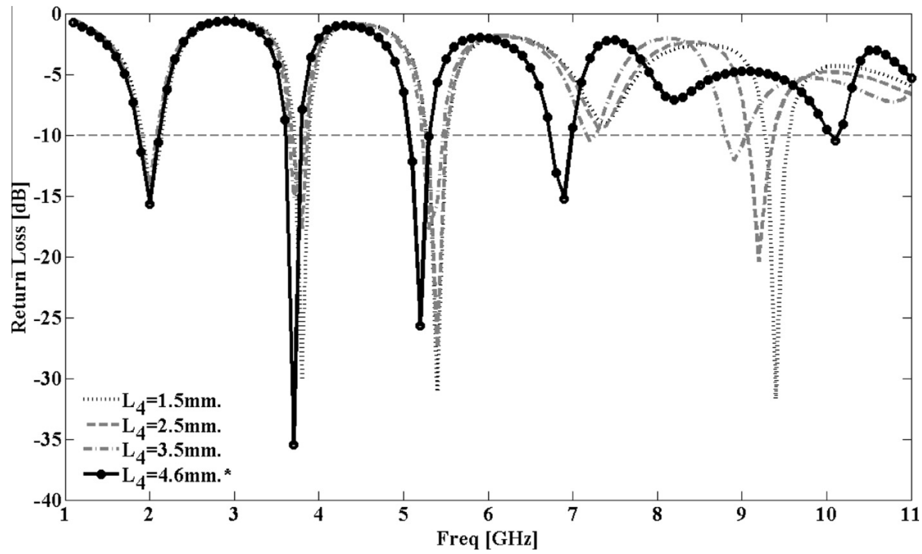

Fig. 5. Simulated return loss characteristics for the proposed antenna with respect to different values of L_4.

Table 2
The process of increasing the resonance frequencies for the proposed antenna.

	Antenna in Fig. 2(a)	Antenna in Fig. 2(b)	Antenna in Fig. 2(c)	Antenna in Fig. 2(d)
Number of resonances	1	2	3	5
Frequency ranges (GHz)	(7.581–7.906)	(4.053–4.269) and (7.542–8.073)	(2.644–2.931), (5.176–5.317), and (7.332–7.707)	(1.988–2.195), (3.659–3.811), (5.171–5.392), (6.782–7.046), and (9.456–9.691)

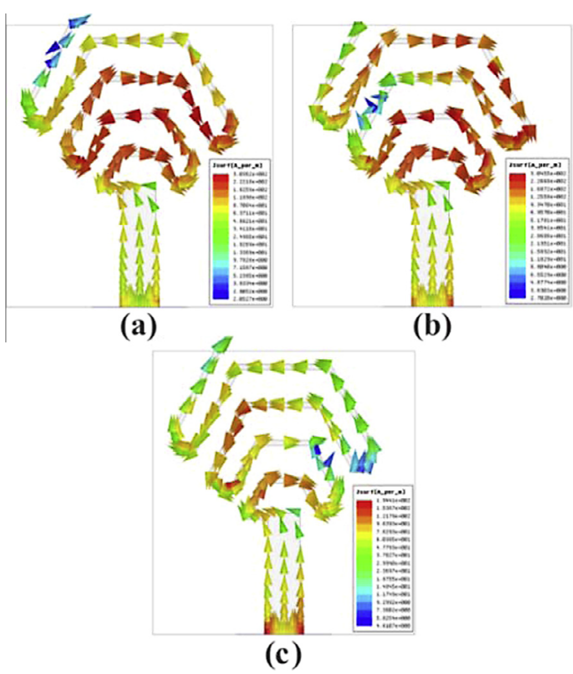

Fig. 6. Simulated surface current distributions on the radiating patch (a) at 2 GHz, (b) at 3.7 GHz, and (c) at 3.4 GHz.

are shown in Fig. 9. The radiation patterns in x-z and y-z planes are approximately omnidirectional for the all frequencies shown in Fig. 9. The electrical properties of the proposed fractal antenna, have been compared to other meander line monopole antenna. It exhibits an acceptable impedance bandwidth, small size and applicable gain (Table 3).

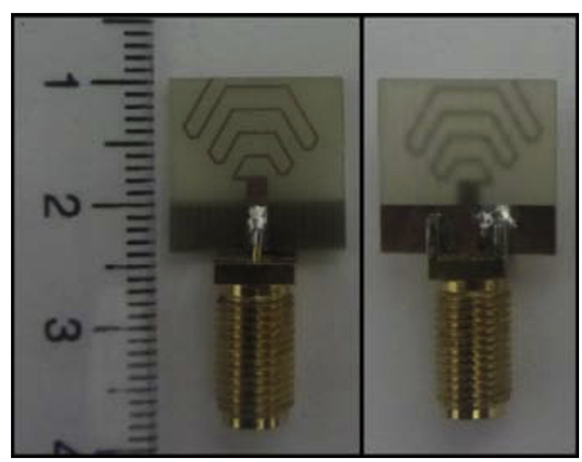

Fig. 7. Photograph of the fabricated antenna prototype with fractal structure.

4. Conclusion

In this paper a novel fractal antenna with crinkle-structure for different applications has been reported. The antenna include crinkle fractal radiating patch and incomplete rectangular ground plane. The antenna has a easy structure and small size. The measurement results show impedance bandwidths of 189 MHz (1.691–1.880 GHz), 212 MHz (3.412–3.624 GHz), 302 MHz (5.139–5.441 GHz). The number of resonance frequencies have been increased due to adding crinkle fractal shapes. Also, the

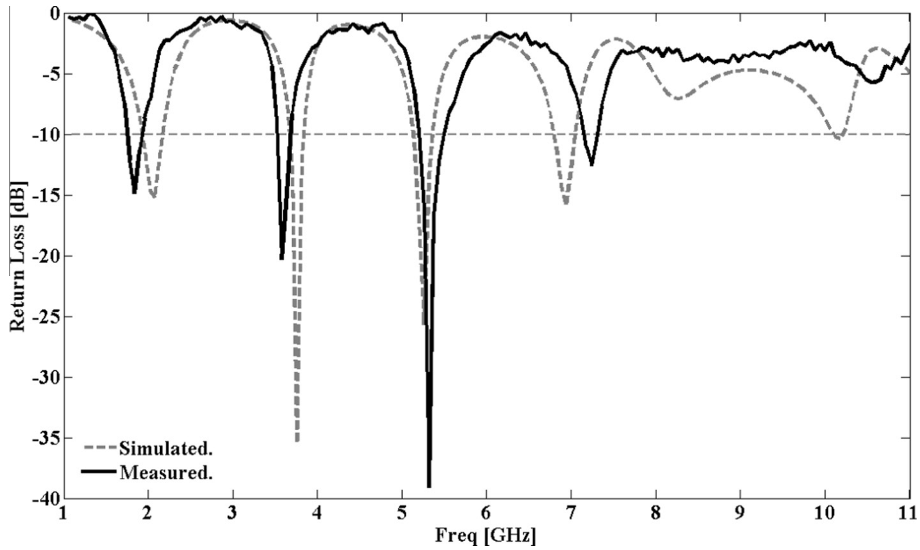

Fig. 8. Measured and simulated return losses of the proposed antenna.

Table 3
Comparison of the proposed antenna with other references.

Refs.	Size (mm^3)	Bandwidth (GHz)	Peak Gain (dBi)
[23]	3.2 × 1.6 × 0.83	0.19 (2.4–2.59)	0.5
[24]	150 × 150 × 0.035	0.03 (1.67–1.7), 0.264 (4.247–4.511)	4.6
[25]	60 × 20 × 0.813	0.08 (2.4–2.48), 0.675 (5.15–5.825)	3.9
This work	14 × 14 × 1	0.189 (1.691–1.880), 0.212 (3.412–3.624), 0.302 (5.139–5.441)	2.7

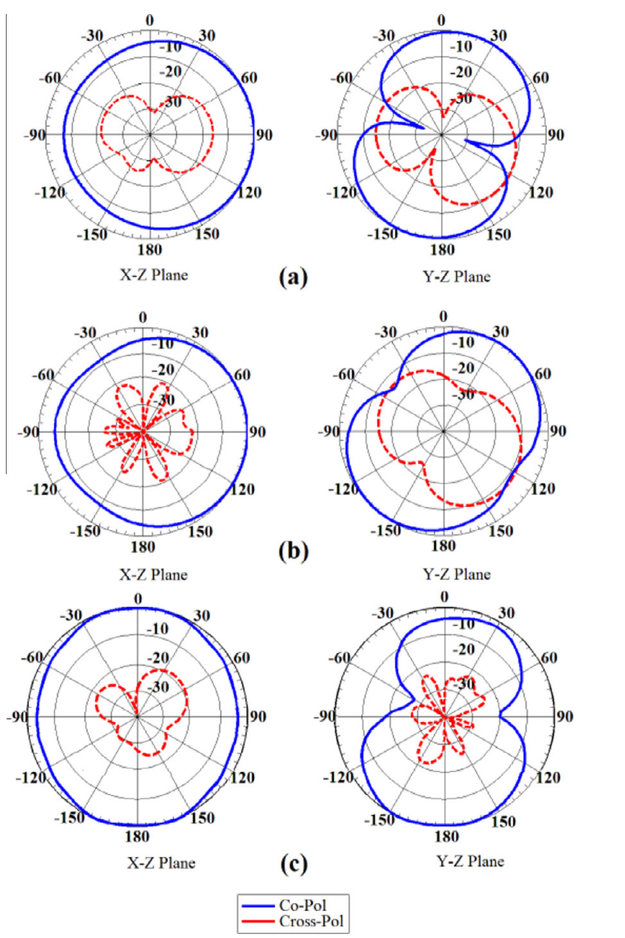

Fig. 9. Radiation pattern of the proposed antenna. (a) 1.78 GHz, (b) 3.52 GHz, and (c) 5.2 GHz.

radiation patterns in both H-plane and E-plane are omnidirectional at the covered frequency bands. The proposed antenna is attractive and can be practical for various multi frequency systems.

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