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A COMPACT DESIGN OF WI-MAX APPLICATION FOR CPW BASED FED KOCH FRACTAL ANTENNA SLOT

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Abstract
A dual big-band CPW-fed modified Koch fractal found out slot antenna, appropriate for WLAN and Wi-MAX operations, is proposed on this paper. right here, the jogging frequency of a triangular slot antenna is faded through the Koch new release approach ensuing in a compact antenna studies on the impedance and radiation trends of the proposed antenna suggest that a modified Koch fractal slot antenna has an impedance bandwidth from 2.38 to 3.ninety 5 GHz and 4.ninety five–6.05 GHz protective 2.four/5.2/5.eight GHz WLAN bands and the 2.five/three.5/5.5 GHz Wi-MAX bands. The antenna directional radiation coverage with a benefit better than 2.0 dBi in the entire working band. Empirical own family members are deduced and in comparison with the results.

Index Terms CPW-fed slot antenna, printed fractal slot antenna, wide-band antenna, WLAN antennas.

INTRODUCTION

The demand for low profile, light weight and low cost broadband antennas has increased in the recent years with the widespread deployment of short distance wireless communications, like the wireless local area networks (WLAN). WLAN's are designed to operate in the 2.4 GHz (2.4–2.48 GHz) and 5 GHz frequency bands (5.15–5.35 GHz and 5.725–5.825 GHz in the United States and 5.15–5.35 GHz and 5.47–5.725 GHz in Europe). Also there is the easily deployable, low cost, broadband wireless access commonly known as Wi-MAX (Worldwide Interoperability for Microwave Access) which is allocated the 2.5–2.69/3.4–3.69/5.25–5.85 GHz bands. Since these standards may be used simultaneously in many systems, there is a need for a single antenna which covers all these bands. Printed slot antennas are attractive because of their planar geometry and wide operating bands [1]. A co-planar waveguide (CPW) feed makes them more suitable for compact wireless communication devices owing to its features like uni-planar structure, easy fabrication and circuit integration. Several slot geometries like square, rectangular, triangular, trapezoidal, circular, elliptical etc. in combination with either a rectangular, fork like or circular tuning stub, optimized for wide-band operation, is found in literature [2]–[11]. Bandwidth enhancement is achieved by employing a feeding scheme that generates multiple resonances. Then by optimizing the distance between the tuning stub and ground surrounding it, the impedance change from one resonant mode to the other is minimized, resulting in wide band operation. Since the lowest resonance of a wide slot antenna depends on the slot boundary [9]–[11], the concept of space filling of the Koch curves used in the design of compact and multi-band patch antennas [12], can also be applied for wide-slot antennas. In this letter, we present a CPW-fed modified Koch snowflake slot antenna operating over a wide frequency band, covering the 2.4/5.2/5.8 GHz WLAN and 2.5/3.5/4.5 GHz WiMAX bands. The proposed design has a compact size (mm , inclusive of the ground plane on FR4 substrate) and wider bandwidth when compared to the slot antennas reported earlier [2]–[5]. Also, the proposed antenna, designed for the WLAN/Wi-MAX 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 [6]–[9]. Even though a wide-band antenna operating from 2.3 to 6 GHz is sufficient, a dual band antenna design would significantly relax the requirements imposed upon the filtering electronics within the wireless device and would be cost-effective. Etching a particular feature in the interior of the radiating element of a planar monopole is a simple means for creating a frequency notch while maintaining the wide-band operation [13], [14]. In this letter, a half wavelength tuning slot is integrated with the wide-band Koch slot antenna for the filter action. This way the antenna achieves dual wide-band operation satisfying the WLAN and Wi-MAX bands simultaneously along with a compact profile by virtue of the Koch fractal based slot geometry.

II. DESIGN

The configuration of the proposed modified Koch slot antenna for dual band operation is illustrated in Fig. 1. The antenna is implemented on a low loss substrate of relative permittivity and thickness .A modified Koch snowflake slot is fed by a 50 CPW feed along with a tuning stub embedded with a U-shaped slot. The antenna performance is analyzed using Ansoft HFSS [15]. The basic geometry of the slot is an equilateral triangle of side , in which repeated iterations are carried out as shown in Fig. 2(a)–(d). Fig. 3 plots the simulated return loss of the antenna (without the tuning slot) for the

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different iteration stages of the Koch geometry starting from the equilateral triangle. The resonant

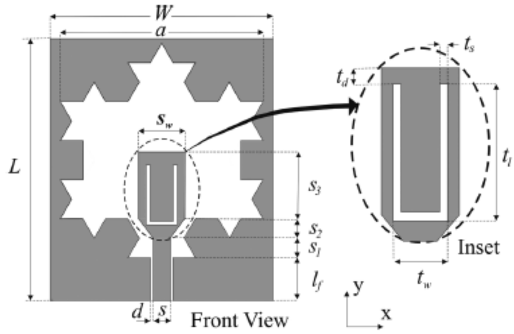

Fig. 1. Proposed slot loaded modified Koch snowflake slot antenna.

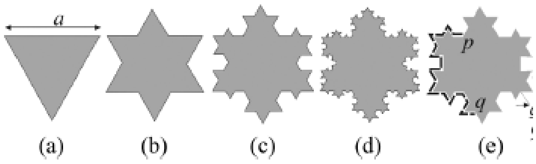

Fig. 2. Koch snowflake geometry in its different iteration stages. (a) Basic geometry. (b) First iteration. (c) Second iteration. (d) Third iteration. (e) Modified second iteration.

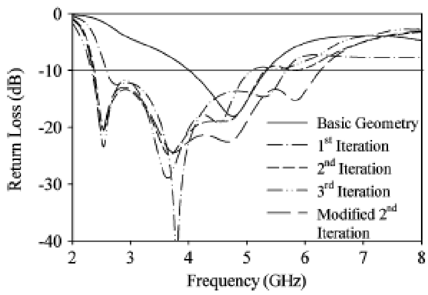

Fig. 3. Simulated return loss of the CPW-fed Koch slot antenna (without the tuning slot)

for different iterations of the slot quency of the slot antenna decreases with the increase in the number of iterations. Even though the perimeter of the slot increases by a factor of 33% with each iteration, the change in resonant frequency does not follow the same order. Also, it is observed that the Koch fractal geometry improves the coupling between the feed stub and the slot, enhancing the impedance bandwidth of the slot antenna. The operating band of the antenna shifts from 4–5.32 GHz to 2.36–5.5 GHz as the number of iterations increase to 2. Further increase in the iteration order causes only a minor reduction in the operating frequency. When the geometry of the second iteration slot is slightly modified asin Fig. 2(e), the operating bandwidth of the antenna is improved to 2.36–6.26 GHz, completely covering the WLAN/Wi-MAX bands. The surface current distribution on the conducting layer and the electric field in the fractal slot are simulated using HFSS and

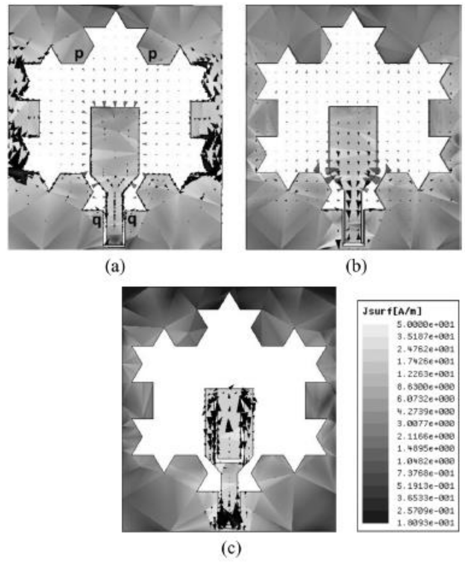

Fig. 4. Simulated current distribution on the patch and the electric field on the slot at (a) 2.5 GHz and (b) 4.55 GHz and (c) 4.55 GHz (with slot).

The plotted in Fig. 4. In the distribution shown in Fig. 4(a), at the lowest resonant frequency (2.5 GHz), a half wavelength variation in current is observed along the fractal boundary of the slot. Based on this, design equations are derived relating the geometry and the operating frequency band of he proposed antenna. Due to the fractal nature of the slot, the perimeter of the Koch curve can be deduced in terms of the side of the basic equilateral triangle geometry. Also, the presence of the dielectric substrate increases the effective dimensions of the antenna lowering the frequencies of operation when compared to that with air as substrate. Hence, the slot boundary , shown in Fig. 2(e), is appropriately related to the wavelength at the first resonance as

$$\frac{\lambda_1}{2} = k \times (pq) \tag{1}$$

where the length of the slot boundary is

$$pq = 17\frac{a}{9} + \frac{a}{3\sqrt{3}} \tag{2}$$

and k is an empirically derived parameter which includes the effect of the substrate. The stub dimensions, shown in Fig. 1, can also be derived in terms of "a" as

$$s_w = \frac{a}{3}, \quad s_1 = s_2 = \frac{a}{6\sqrt{3}}, \quad s_3 = \frac{a}{2\sqrt{3}}. \tag{3}$$

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The size of the ground plane on the feed side is fixed by the length to 5 mm while the ground plane edges on the rest of the three sides are about 1 mm away from the vertex of the slot.

TABLE I
ANTENNA DETAILS

Antenna	Laminate	ε_r	h(mm)	s(mm)	d(mm)	k	a(mm)	LxW(mm²)	Computed(mm)			Optimised(mm)		
									s_1, s_2	s_3	s_w	s_1, s_2	s_3	s_w
1	RT/duroid® 5880	2.2	1.57	2.8	0.15	1.03	28	35.5x30.5	2.7	8.1	9.33	2.7	10.6	9
2	Nalco NH9338	3.38	1.57	2.4	0.3	1.07	27	34.5x29.5	2.6	7.8	9	2.6	9.3	8.4
3	FR4 Epoxy	4.4	1.6	2.2	0.3	1.11	26	33.5x28.5	2.5	7.5	8.7	2.5	9.1	6.4
4	RT/duroid® 6006	6.15	1.27	2.0	0.4	1.15	25	32.5x27.5	2.4	7.2	8.3	2.4	7.5	7.2
5	RT/duroid 6010LM	10.2	1.27	2.0	0.7	1.2	24	31.5x26.5	2.3	6.9	8.0	2.3	7.3	5.6

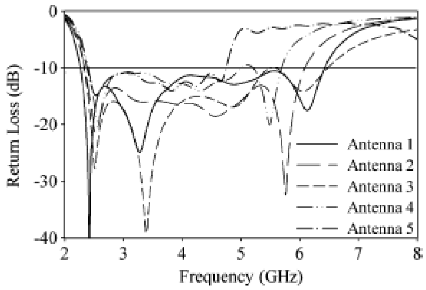

Fig. 5. Return loss of the antennas with parameters as in Table I.

TABLE II
COMPUTED AND MEASURED FOR DIFFERENT SLOT SIZES OF ANTENNA 3

a(mm)	18	22	26	38
f_{r1}(GHz) Computed	3.6	2.95	2.5	2.32
f_{r1}(GHz) Measured	3.54	2.98	2.51	2.34
Band (GHz)	3.2-7.6	2.74-6.96	2.32-6.5	2.16-5.88

The validity of the above equations is confirmed by designing the proposed antenna on different substrates for the 2.4/5 GHz operation. The parameters are given in Table I, along with corresponding values of and the simulated return losses are plotted in Fig. 5. Similarly, using (1)–(3), the proposed antenna was designed for operation in different frequency bands by varying a from 18 to 28 mm as tabulated in Table II. It is observed that equations are valid for all substrates and for different slot sizes considered. However, Antenna 5 exhibits a reduced bandwidth from 2.38 to 4.74 GHz.

A half wavelength slot etched out on the tuning stub of the wide-band antenna notches out the corresponding frequency leading to a dual wide-band operation. Fig. 6 plots the simulated return loss of the antenna for different slot lengths. As the slot length increases from 19.6 mm mm to 21.6 mm mm , the notched frequency shifts from 5.0 to 4.3 GHz, following (4) as

$$\text{slot length} \approx \frac{c}{2 f_{\text{notch}}} \left(\sqrt{\frac{\varepsilon_r + 1}{2}} \right)^{-1}.$$

The surface currents on the patch at 4.5 GHz are shown in Fig. 4(b) and (c), with and without the slot. It shows how the excited surface currents on the antenna interfere destructively

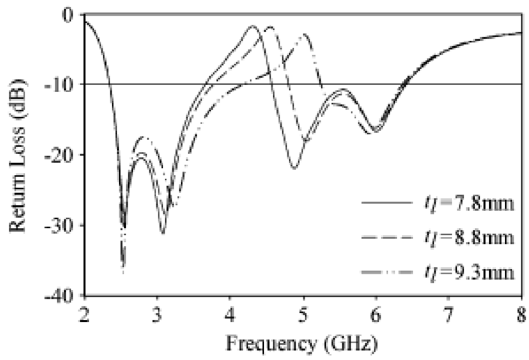

Fig. 6. Return loss of the antenna for different slot lengths

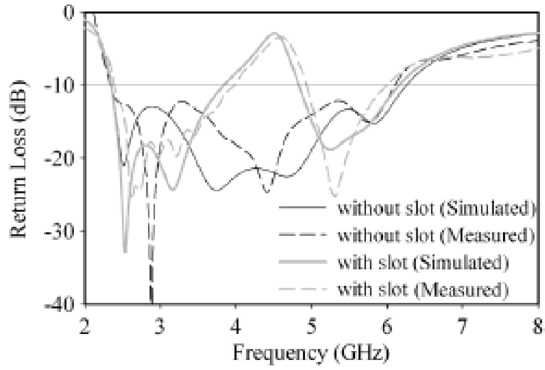

Fig. 7. Return loss of the antenna with and without the slot

due to the presence of a slot in the tuning stub mm ,hence causing the antenna to be non-radiating at that frequency.

III. RESULTS

The prototype of proposed antenna (Antenna 3), with dimensions as in Table I, is fabricated and its impedance and radiation characteristics were measured using Rhode and Schwarz ZVB20 Vector Network Analyzer. The simulated and measured return loss of the antenna plotted in Fig. 7, show good agreement. The 10 dB bandwidth of the wide-band antenna (without the slot) is 3.77 GHz (2.33–6.1 GHz). With the tuning slot, the antenna gives dual wide-band performance with a 10 dB bandwidth of 1.57 GHz (2.38–3.95 GHz) and 1.1 GHz (4.95–6.05 GHz) in the lower and upper bands respectively.

Thus, it covers the 2.4–2.484 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz WLAN bands, and the 2.5–2.69 GHz,

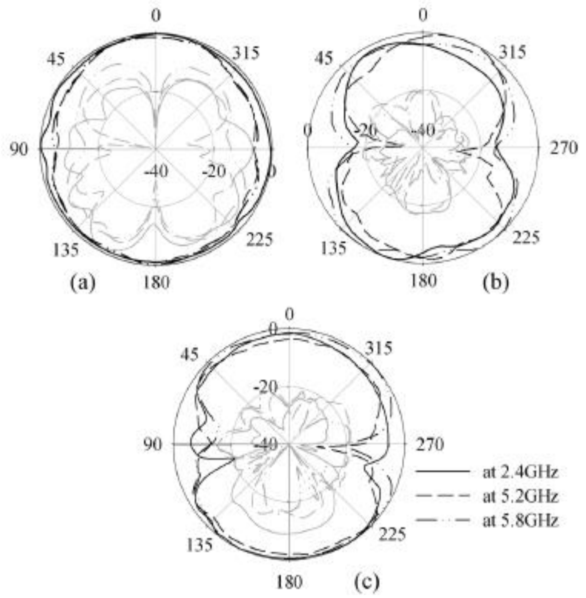

Fig. 8. Radiation pattern of the antenna

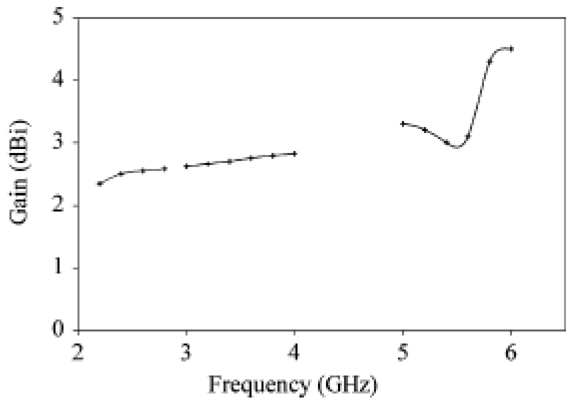

Fig. 9. Gain of the proposed design (Antenna 3).

3.4–3.69 GHz, and 5.25–5.85 GHz Wi-MAX bands. The measured radiation patterns of the antenna in the planes are shown in Fig. 8. It is observed that the radiation patterns are stable, omni-directional and with polarization planes along the axis over the entire operating band. Cross-polarization is observed in the plane due to the strong horizontal component of electric field as is evident from Fig. 4(a). The measured gain of the antenna in the operating bands is plotted in Fig. 9. It is seen that the gain remains above 2.0 dBi in the entire band. Simulation studies indicate that the antenna radiation efficiency is greater than 85% throughout the operating band.

CONCLUSION

Design of a CPW-fed modified Koch fractal printed slot antenna, suitable for WLAN 2.4/5.2/5.8 GHz and Wi-MAX 2.5/3.5/5.5 GHz operations, is presented. Simulated results showed that the introduction of a Koch fractal slot instead of the triangular slot geometry lowers the frequency of operation along with wide-band matching. The antenna size inclusive of the ground plane is compact and a simple tuning slot ensures dual wide-band operation covering the WLAN bands and WiMAX bands. Empirical equations are deduced and validated to design the antenna on different substrates. Results indicate a large impedance bandwidth with relatively stable and omnidirectional radiation patterns which makes the design suitable for broadband wireless communication applications.

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