A compact stacked Quasi-fractal microstrip antenna for RFID applications

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Abstract- **In this paper, we propose a new compact quasi-fractal shaped microstrip antenna that consists of a hexagonal patch as the main radiator and a complementary stacked patch as the parasitic element. The overall surface of the proposed quasi-fractal patch is about 55% lower than the conventional hexagonal patch. Using the stacked technique, the gain reduction of the compression technique is almost compensated for the proposed antenna while the total gain is reduced by about only 1 dBi. Experimental results show that the operation frequency of microstrip antenna is about 2.5 GHz which covers the microwave frequency band of radio-frequency identification systems.**

Index Terms- compact stacked microstrip antenna, quasi-fractal shaped antenna, RFID applications.

I. INTRODUCTION

Radio-frequency identification (RFID) is a wireless method for data transfer in objects identification and tracking. In this method, an interrogation signal from the remote reader is sent to tag or transponder also the backscattered modulated signal from the tag is sent to the reader. The RFID reader acts as an access point for RFID tagged items so that the tags' data can be made available to business applications. A schematic RFID system is shown in Fig. 1. The RFID systems can be distinguished by their operating frequency ranges. All of the frequency ranges for RFID applications can be classified as shown in Table I.

Microstrip Antenna is one of the common antennas used in RFID readers. This antenna has several attractive properties such as lightweight, low-cost and easy fabrication. Today the fast decrease in dimensions of RFID readers has led to the requirement for more compact microstrip antennas. This issue has been addressed by a multitude of techniques such as using the substrate with high dielectric constant [1], incorporating shorting pin in the microstrip patch [2]-[3], cutting slots in the radiating patch [4] and using the fractal shapes for design of radiating patch [5].

Generally, the fractal shapes are self-similarity geometries on all scales or iterations with a fixed generator [6] such as Koch [7] and Minkowski [8].

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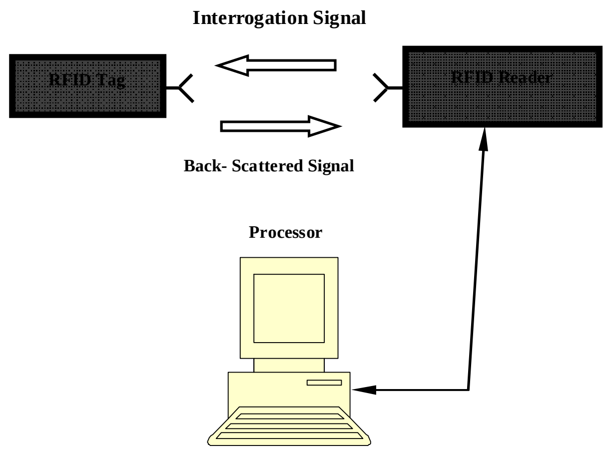


Fig. 1. Typical schematic of a RFID system.

TABLE I. Frequency ranges of RFID systems

Band	**Frequency (MHz)**
Low frequency (LF) band	0.009-0.135
High frequency (HF)band	13.56, 27.125, 40.68
Ultra-high frequency (UHF) band	433.9, 869, 915
Microwave band	2.5, 5.8, 24.125

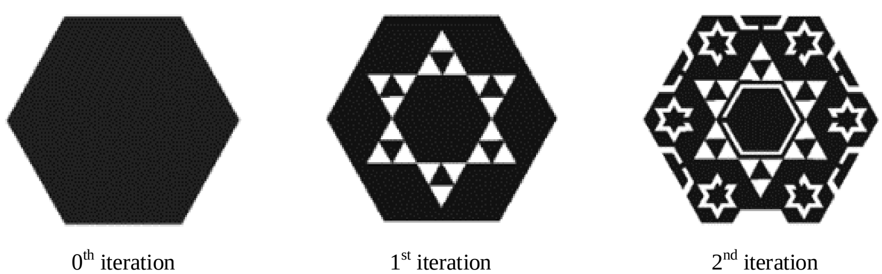


Fig. 2. The scheme of the proposed hexagonal quasi-fractal geometry.

In this paper, we propose a new quasi-fractal patch antenna with hexagonal configuration. The 0^{th}, 1^{st} and 2^{nd} iteration of the proposed fractal geometry are shown in Fig. 2. As shown in this figure, each iteration does not use a fixed generator for making the next iteration. So, the structures shown in Fig. 2 do not present a complete fractal geometry. A modification in each iteration compared to the last iteration is used to improve the antenna performance.

Decreasing gain is the main drawback in the design of compact microstrip antenna that can be solved by using of array structure, multilayer and stacked method [9]. The gain reduction of the proposed technique is almost compensated by using a parasitic patch on top of the main radiator and a resonant slot on the ground plane. The measured results confirm that the proposed antenna can be

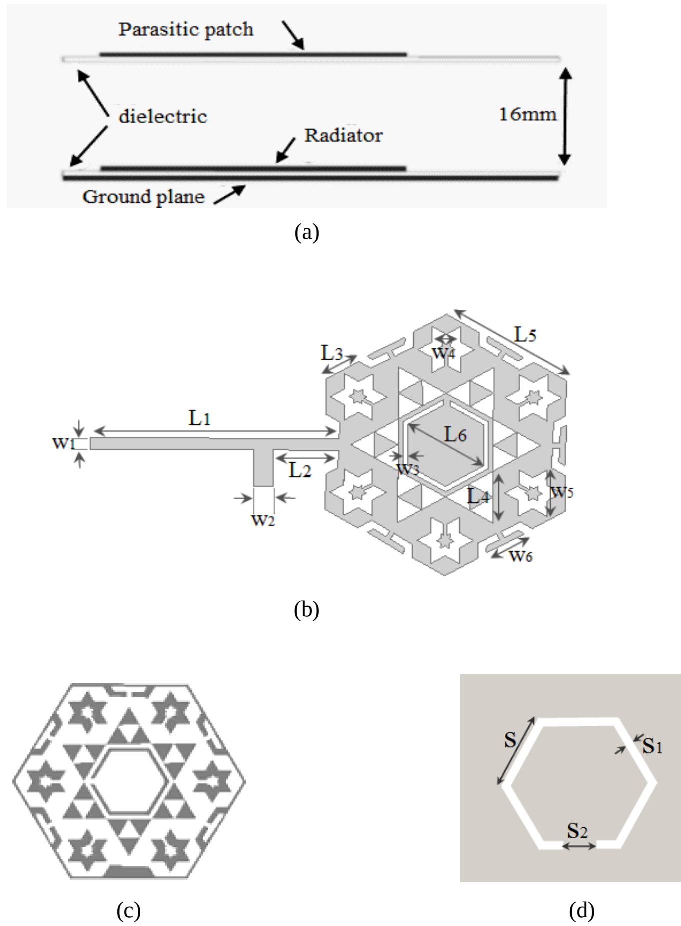
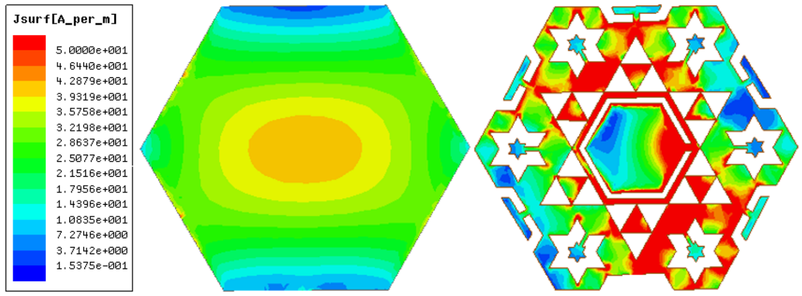


Fig. 3. Configuration of the proposed antenna.(a) Cross Sectional view(b) Main fractal patch with feed line(c) Complementary parasitic patch(d) Ground plane

used in microwave band of RFID readers with about 4dBi gain and can reduce up to 55% on the antenna surface.

II. PROPOSED ANTENNA GEOMETRY DESIGN

Fig. 3 shows the geometry of proposed antenna. As shown in this figure, the antenna consists of two metallic patches. The main patch is the 2nd iteration of the quasi-fractal geometry given in Fig. 2. As shown in Fig. 3 (b), the main patch is fed by the microstrip line and one tuning stub is used to provide a good impedance matching. Fig. 4 shows the current distribution of the proposed main fractal patch and the conventional hexagonal patch at the frequency of 2.5 GHz. Compared to simple hexagonal patch, the current path for dominant mode is increased in the proposed patch. It means that at the same frequency of operation, the proposed quasi-fractal patch has lower surface than the simple hexagonal patch. However, this compression technique decreases the antenna radiation gain.



(a) (b)

Fig. 4. Current distribution at 2.5 GHz. (a) simple hexagonal patch (b) proposed main patch

To overcome this drawback, two gain improvement techniques are used in the proposed antenna. As a first, a parasitic patch is placed on top of the main patch as a stacked layer (See Fig. 3). According to the Babinet's principle, the parasitic patch is chosen as complementary of the main patch. This choice increases the gain at the broadside and improves front to back ratio. As the second technique, a hexagonal slot is also etched on the ground plane as complementary split ring resonator (CSRR). In fact, this CSRR slot changes the capacitance per unit length and the effective permittivity of the substrate. This can improve antenna parameters such as gain. It is impossible to determine the slot dimension accurately. Based on current distribution on ground plane at resonant frequency, the dimension of this slot can be approximated by:

$$f = \frac{c}{2\sqrt{\varepsilon_{eff}}\,L} \quad (1)$$

$$L = 6\times S - S_2 - 6\times S_1 \quad (2)$$

Where c is the free space velocity of light, (ε_{eff}) is effective permittivity and L is the average of loop lengths (See Fig. 3(d)). By using of current distribution on the ground plane at the resonant frequency, the best place of the slot on the ground plane is found exactly under the main patch where the slot cuts the maximum current lines.

III. RESULTS AND DISCUSSION

To cover the microwave band of RFID reader (2.5 GHz), the all dimensions of the proposed structure in the previous section are designed and optimized as follows:

$$w_1 = 1.2,\ \ w_2 = 1.86,\ \ w_3 = 0.5,\ \ w_4 = 1.73,\ \ S_1 = 0.5mm$$

$$w_5 = 4.82,\ \ w_6 = 4.13,\ \ L_1 = 24.51,\ \ L_2 = 6.46,\ \ S_2 = 10mm$$

$$L_3 = 3.4,\ \ L_4 = 5.4,\ \ L_5 = 13.5,\ \ L_6 = 8.6,\ \ S = 13.5mm$$

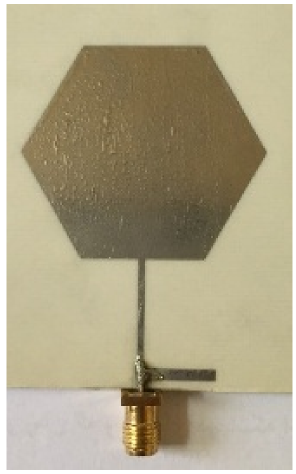


Fig. 5. Photograph of the fabricated conventional hexagonal antenna

Fig. 6. Photograph of the fabricated proposed antenna

Where the both of dielectric layers are RO4003 with thickness h=0.812 mm, surface area 70×70 mm2, dielectric constant εr = 3.55, and $\tan\delta$ = 0.0027. As shown in Fig. 5 and Fig. 6, the both of conventional hexagonal and proposed antenna are fabricated.

Fig. 7 shows the simulated and measured results of reflection coefficient for the proposed antenna compared with the conventional hexagonal patch. The all simulated results are achieved by commercial software HFSS which utilized a finite element method (FEM) and by integral equetion (IE) called method of moments (MOM). However, the both of conventional and proposed antenna is designed to cover the frequency of 2.5 GHz, the measured resonance frequency of the proposed antenna is about 5% lower than the simulated one. This difference is caused by the inaccuracy of fabrication and montage process.

Based on above design parameters, the overall surface of the proposed compact antenna is about 55% lower than the conventional hexagonal patch (the largest in-plane dimension of the proposed quasi-fractal patch and the conventional hexagonal patch is 27mm and 40 mm respectively).

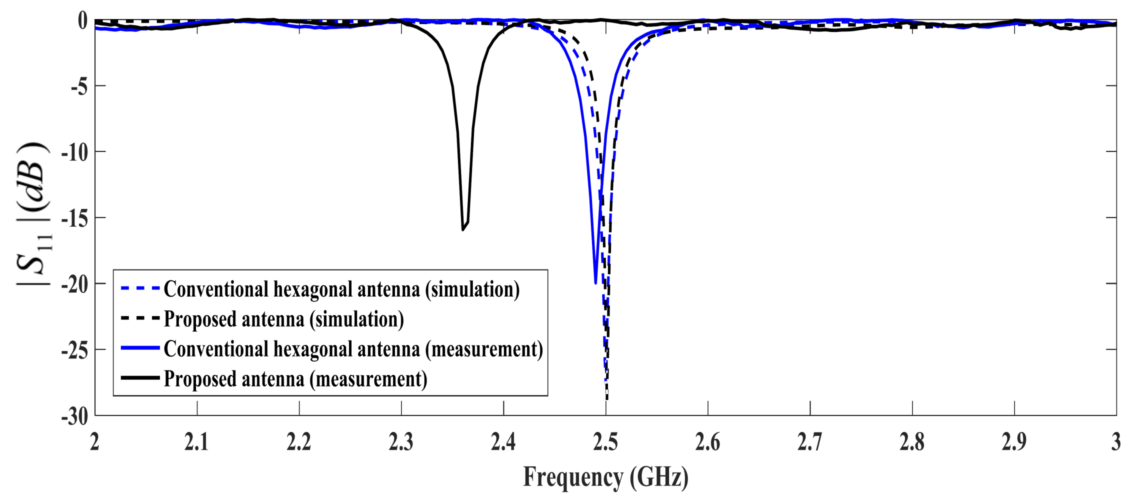


Fig. 7. Simulated and measured results of reflection coefficient for the proposed and the conventional hexagonal patch

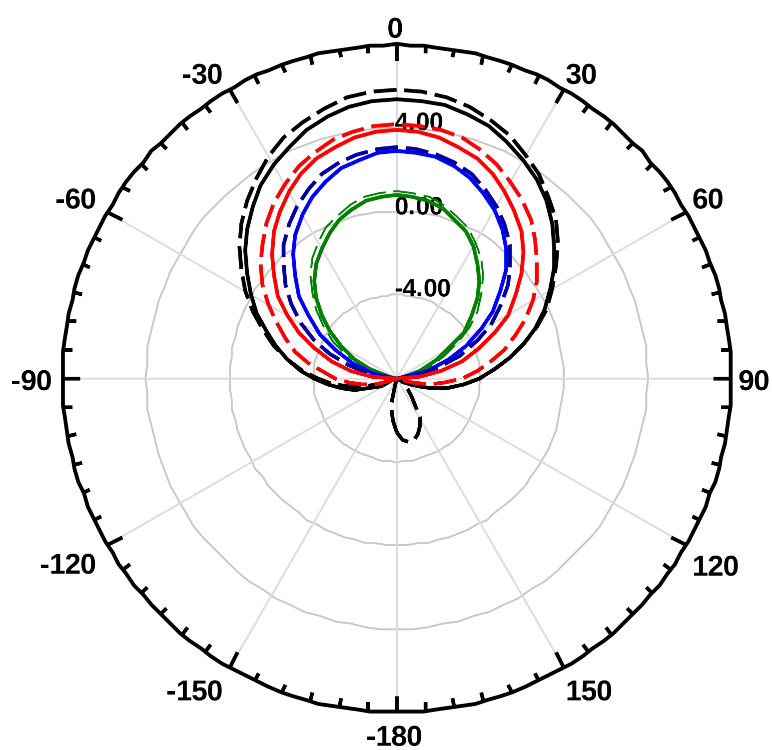


Fig. 8. Radiation pattern. finite element method (dash line), method of moments (solid line).
Conventional hexagonal antenna (black line), The only main patch (without slot on ground and parasitic patch) (green line)
Proposed stacked quasi-fractal antenna (red line), Stacked quasi-fractal antenna (without slot on ground) (blue line)

TABLE II. The gain improvement of the proposed antenna

Type	Gain (dBi)
Conventional hexagonal antenna	**5.4**
Proposed stacked quasi-fractal antenna	**4.3**
Stacked quasi-fractal antenna (without slot on ground)	**2.9**
The only main patch (without slot on ground and parasitic patch)	**0.5**

As shown in Fig. 8, the simulated radiation patterns of the proposed antenna at the resonance frequency are compared with the conventional hexagonal patch. The effect of the main patch,parasitic patch and slotted ground plane on radiation pattern and gain are considered in this figure and Table II, respectively. Based on results given in Table II, the gain of the antenna in direction of beam is increased when the complementary parasitic patch and slotted ground are used. Compared to the conventional hexagonal antenna, the broadside gain reduction of the proposed antenna is only 1.1dBi while we have 55% reduction in the overall antenna surface.

IV. CONCLUSION

In this paper, a new compact quasi-fractal microstrip antenna based on hexagonal geometry is proposed for microwave RFID reader. Based on simulation and measurement results, the overall surface of the proposed patch is about 55% lower than conventional hexagonal patch at the same resonance frequency. By using of stacked technique, the gain reduction of compression technique is almost compensated for the proposed antenna.

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