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A Novel Design of Compact Dipole Antenna for 900 MHz and 2.4 GHz RFID Tag Applications

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Abstract—A novel design of fractal dipole antenna has been presented for RFID (Radio Frequency Identification) tag applications, which is based on the fractal theory. The antenna consists of two third iteration triangle fractal arms, and has been designed to work at 900 MHz (GSM) and 2.4 GHz (ISM), and its size is 89 mm × 29 mm × 1.6 mm. The simulated results for various characteristics of the antenna have been shown using finite element technique based commercial software ANSOFT HFSS. The simulated and measured impedance results are in good agreement.

1. INTRODUCTION

A RFID system can be composed of a tag, a reader, a central processing system and user terminal equipment. A typical UHF RFID tag is composed of tag chip and antenna. For the diversity of the application requirements, the miniaturization and deformation design are the core of the tag design.

In order to improve the reading distance, the impedance of the designed antenna should be properly matched with the tag chip impedance. For this reason, impedance matching is the main problem of the tag antenna design [1].

A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume. Fractal antennas are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communication [2].

Different kinds of fractal antennas have been studied in several research articles, such as Sierpinski monopole [3] Koch curves monopole [4] and tree monopole [5], they verified that fractal antennas has size-reducing feature within the limited space however they are not applicable to the tag antenna design. In this article, we use fractal shape to replace the dipole arms and in order to match with most chips, a matching loop is designed in the middle of the arms. And it's the main improvement in our study.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure 1, which consists of two fractal arms and using an inductively coupled feeding rectangular loop.

Each arm is the third iteration of the Hilbert fractal structure. The dimensions of fractal branches are taken so that the dipole without the rectangular loop is matched to the classical 50 Ω reference impedance port at 900 MHz. This antenna is printed on FR4 substrate with relative permittivity of 4.32, and the thickness of the substrate is 1.6 mm. The trace width of the antenna is 1 mm. The resonant frequency of the antenna is mainly depended on the length of the arms. The loop location 'h' is the gap between the lower boundary of rectangular a and rectangular s. By adjusting the loop length

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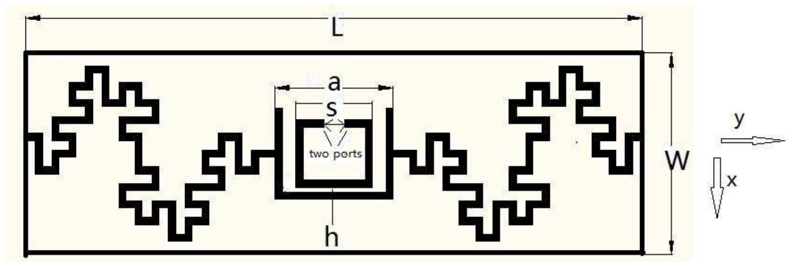


Figure 1. Geometry of the proposed antenna.

's' and the parameters 'h', the impedance of the tag antenna can be matched to any chips. The two ports at the center of the loop is the location of chip. Finally, the designed antenna dimension is about 89 mm × 28 mm, it amounts to $0.27\lambda \times 0.085\lambda$, where λ is the wavelength in free space at the center frequency 900 MHz.

3. SIMULATION AND MEASUREMENT RESULTS

First of all, a parametric study is presented using commercially available software Ansoft HFSS.

As shown in Figure 2 and Figure 3, the loop length 's' obviously influences the real part and

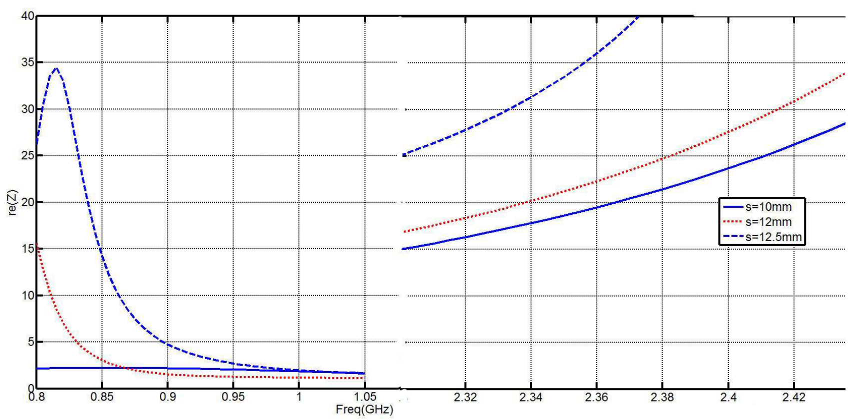


Figure 2. Real part at $s = 10$, 12, 12.5 mm.

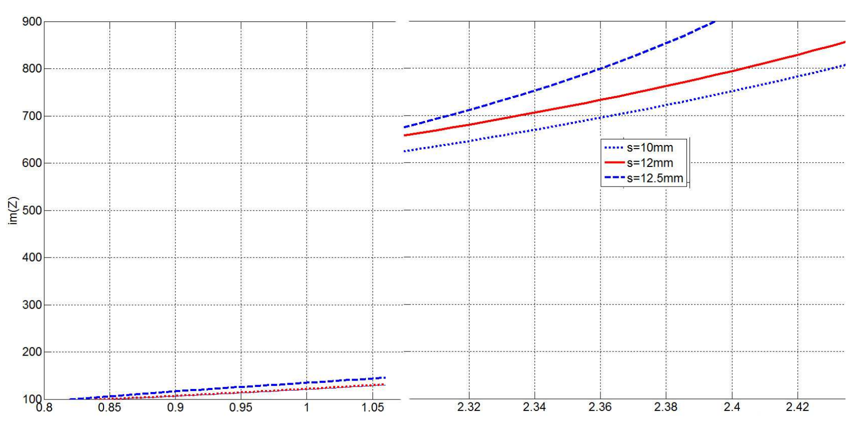


Figure 3. Imaginary part at $s = 10$, 12, 12.5 mm.

imaginary part of impedance. The other parameters are $L = 89\,\mathrm{mm}$ and $W = 28\,\mathrm{mm}$, $a = 17\,\mathrm{mm}$, $b = 12\,\mathrm{mm}$, $h = 1\,\mathrm{mm}$. It noted that the loop length influences the reactance more strongly than the resistance of the impedance of the tag antenna.

As shown in Figure 4 and Figure 5. The loop location parameter 'h' may also strongly effect on

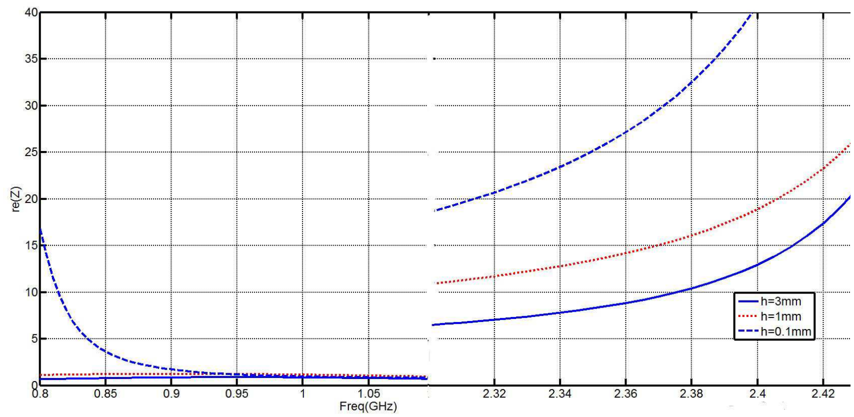


Figure 4. Real part at $h = 0.1$, 1, 3 mm.

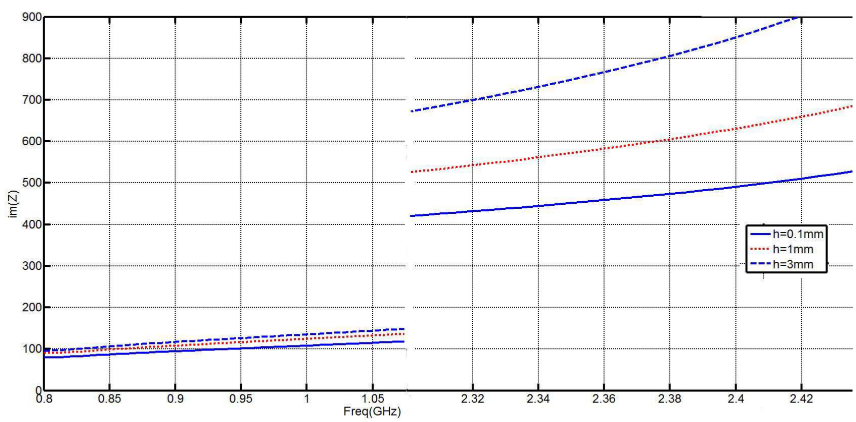


Figure 5. Imaginary part at $h = 0.1$, 1, 3 mm.

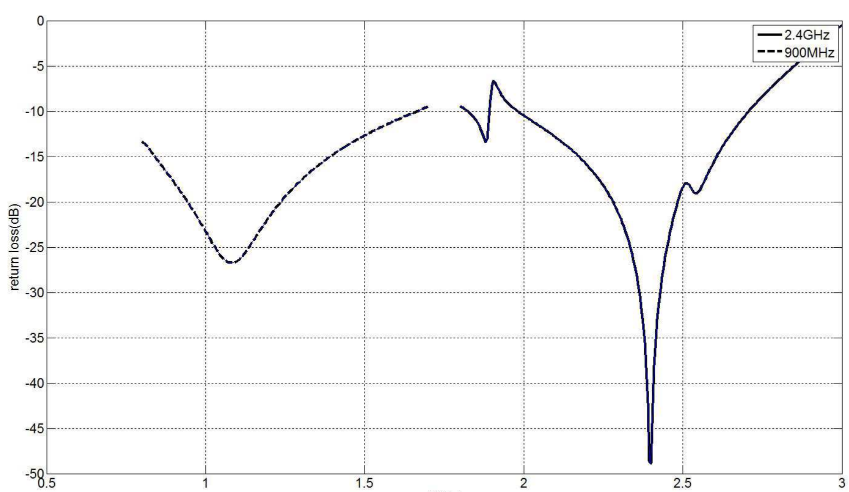
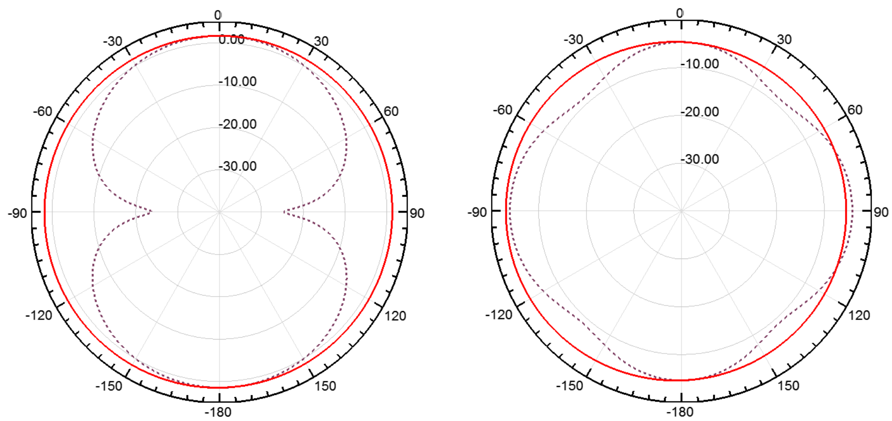


Figure 6. Simulated return loss.

impedance.

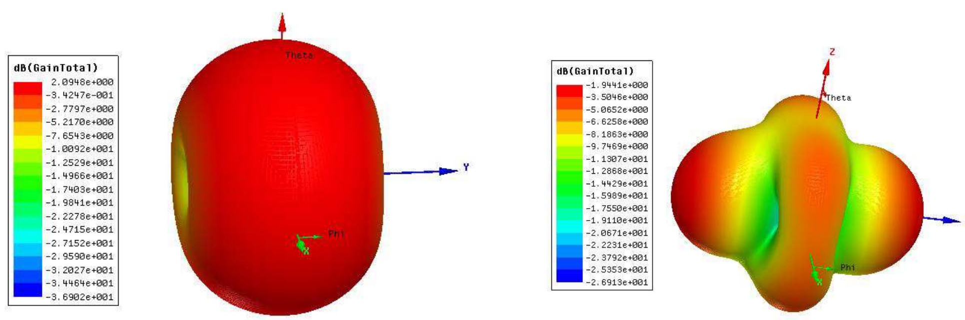
By adjusting these two parameters, the designed antenna can be matched at a wide range. Many microchip has the impedance ($7 < R < 40\,\Omega$) and ($105 < -X < 151\,\Omega$) at 900 MHz; ($5 < R < 30\,\Omega$) and ($450 < -X < 800$) at 2.4 GHz. So the designed loop can be perfectly used to achieve matching to most chips.

As shown in Figure 12, the surface current gives the good explanation why the proposed antenna can work at both frequencies. At 900 MHz, the current flows to the end of two arms in y direction, meanwhile, at 2.4 GHz, the current flows to the end of two arms in x direction. The length of each arm in y direction is obviously longer than it in x direction. It also can be explained the reason why the maximum radiation direction is different at each frequency.



(a) 900 MHz (E plane - - - H plane —) (b) 2.4 GHz

Figure 7. Simulated radiation patterns (Phi = 0 deg — xOz, Phi = 90 deg — yOz).



(a) 900 MHz (b) 2.4 GHz

Figure 8. Simulated radiation patterns at 3D polar.

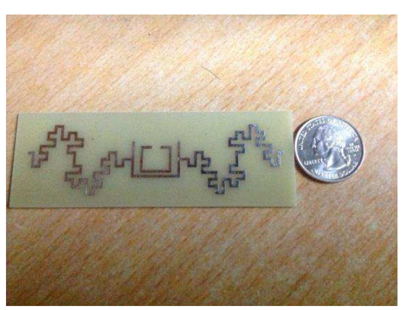


Figure 9. Photograph of the fabricated antenna.

The simulated return loss versus frequency characteristic of the proposal antenna is shown in Figure 6. It is optimized to be matched with commercial tag (EPC GEN 2), which has input impedance of $(14 - j144)$ at 900 MHz and $(14 - j650)$ at 2.4 GHz. The figure shows that the reflection coefficient is good witch is about -20 dB at 900 MHz, and -50 dB at 2.4 GHz. The radiation pattern is shown in Figure 7 and Figure 8. It is shown that the designed antenna is quite good at lengthening the reading

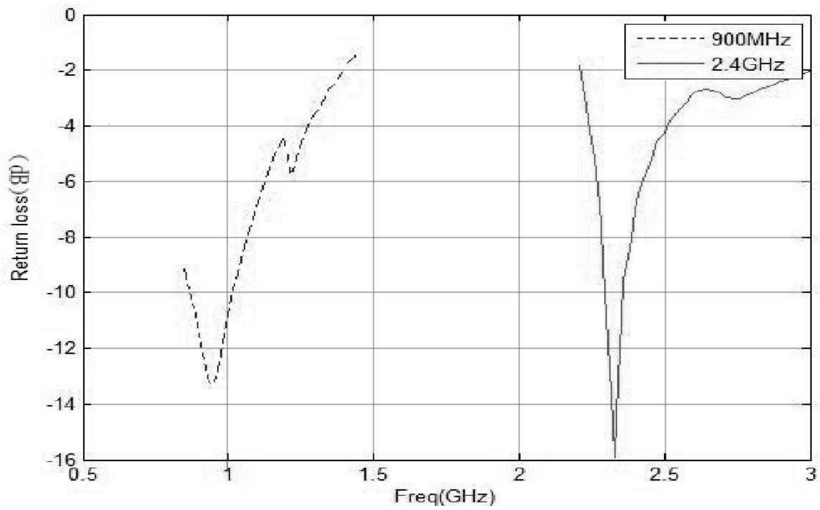
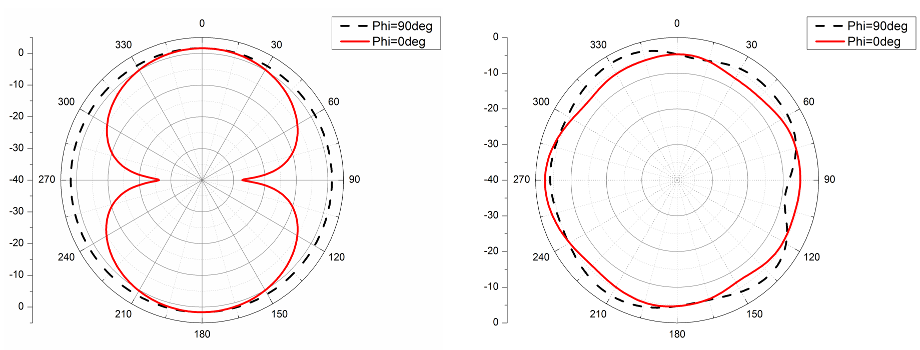
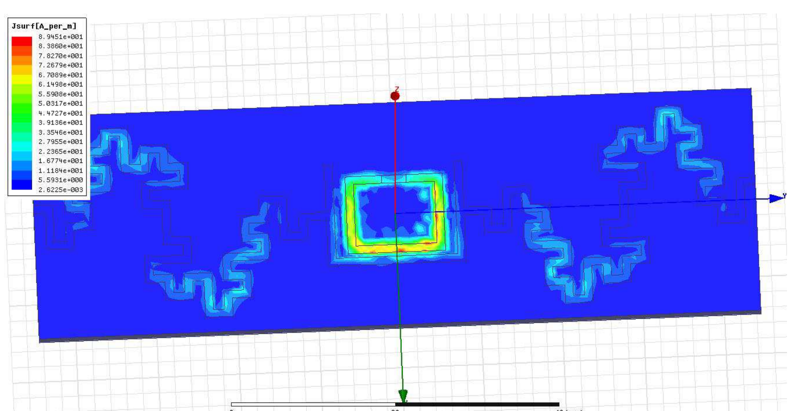


Figure 10. Measured return loss characteristic.

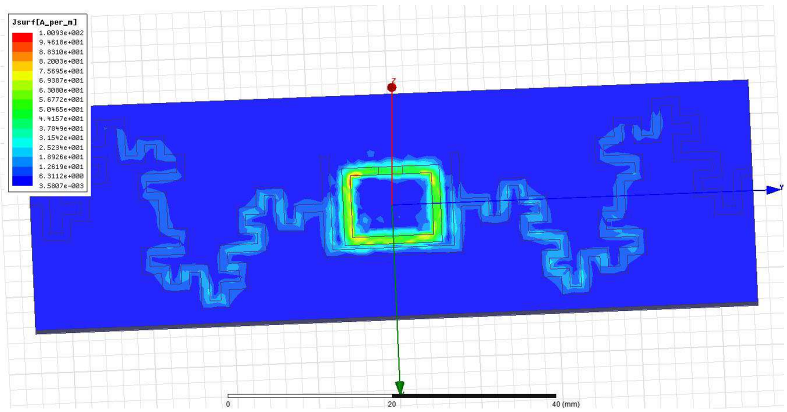


(a) 900 MHz (b) 2.4 GHz

Figure 11. Measured radiation patterns (Phi = 0 deg — xOz, Phi = 90 deg — yOz).



(a)



(b)

Figure 12. (a) Surface current at 900 MHz. (b) Surface current at 2.4 GHz.

distance.

The photograph of the fabricated antenna is shown in Figure 9. The proposed antenna has been fabricated easily in our work-shop. The measured return loss characteristic is shown in Figure 9. And the measured radiation pattern is shown in Figure 10. The simulated and measured return loss characteristics are in good agreement.

4. CONCLUSION

In this study, a novel design of a fractal antenna is proposed. This antenna reduces the dimension and can be very easily matched with any commercial chips. A coupling loop is used to adjust the input impedance of the antenna and make it suitable for various applications. The proposed antenna can be used in GSM (900 MHz) and communication system (2.4 GHz), just like different kinds of small RFID readers, wireless sensor network nodes and so on.

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