A High Gain and Multiband Patch Antenna with Semi Fractal Structure

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Abstract. In the present paper, a high gain and multiband patch antenna with semi fractal structure is designed. The patch antenna owns a hexagonal shape with the longest diagonal being 52.99mm. At the edge of the patch, an angle was cut to adjust the input impedance characteristics of the antenna as well as minimize its radiation size. We employ the FDTD method to calculate its radiation properties. Results show that the radiation gain can reach 6.95dBi at 2.45GHz with a good radiation pattern, which manifests itself a great potential application in radio frequency identification (RFID) industry.

1. INTRODUCTION

In 1999, the concept of the Internet of things has been formally put forward at the Massachusetts Institute of Technology. It was defined as: to connect all the items via radio frequency with the Internet to intelligently identify information and realize smart management [1]. A decade later, a few developed countries, including the United States, Europe, Japan and South Korea networked to enhance national development strategy. Since then, the Internet of things has entered a substantive stage of development. The RFID, as a core technology to the Internet of things, plays a vital role to the development of the Internet of things. The most noteworthy feature of RFID technology is non-contacting, therefore, antennas become the indispensable element in RFID technology. Nowadays, the investigation of RFID antennas is mostly concentrated in radio frequency band, however, the investigation of employing super high frequency and microwave bands are still in the initial stage. Also, due to the miniaturization of RFID antennas and the surface characteristics they attached, how to improve the efficiency of the RFID antennas in a limited space is still facing challenge.

Fractal geometry is a geometric structure with self-similar characteristics between the local morphology [2-3]. Therefore, the fractal is a kind of iterated geometry independent of the scale, which is similar to the frequency independence of the wideband antenna. The American scientist Cohen found that when employing fractal geometry in antenna design, it possessed incomparable advantages over traditional antennas, regardless of the size of antenna [4-7]. Subsequently, systematic research on fractal antennas has been widely roused in the research institutions all over the world [8-12]. The research results show that the fractal characteristic endows antennas two major advantages better than traditional antennas, which includes reducing antenna size and increasing working frequency band, which has a great influence on the radiation and impedance characteristics of an antenna. Also, when fractal dimension with high space filling efficiency is employed to design antennas, such as the Koch
monopole and dipole antennas [13-14], fractal tree antennas [15] and fractal loop antennas [16], the antenna size decreases and is close to the fundamental limits of electrically small antenna, which can fully reduce the size of mobile communication equipment.

In the present paper, we also design a fractal antenna that works at multiband frequencies, including at 2.45GHz frequency for RFID system. It is a semi-fractal patch antenna, whose area is small with high radiation gain, improving the identification distance in the application of RFID industry.

2. THE STRUCTURE OF THE SEMI-FRACTAL ANTENNA

The structure of the patch antenna is illustrated in Fig.1, which is composed of a semi-fractal structure fed by coaxial line. The parameter L1 represents the length of the patch on Y axis, while L2 is the width of the patch at X axis. The coaxial feeding point is on the Y axis, which is L0 mm away from the center point of the radiation patch. The thickness of the dielectric substrate is H=5.00mm and the substrate material is FR4 with the relative permittivity of ε=3.38.

\[
L_{1} = \frac{c}{2f} \left( \frac{\varepsilon + 1}{2} \right)^{\frac{1}{2}}
\]

\[
L_{2} = \frac{c}{f \sqrt{\varepsilon_{e}}} - 2\Delta L
\]

where, f is the center frequency of 2.45GHz, c is the velocity of light. \(\varepsilon_{e}\) and \(\Delta L\) are the effective permittivity and the equivalent radiation gap length, which can be calculated by Equ.(3) and Equ.(4) respectively.

\[
\varepsilon_{e} = \frac{\varepsilon + 1}{2} + \frac{\varepsilon - 1}{2} \left( 1 + \frac{12H}{L_{2}} \right)
\]
\[ \Delta L = 0.412H \frac{(\varepsilon + 0.3)(L_z / H + 0.264)}{(\varepsilon - 0.258)(L_z / H + 0.8)} \] (4)

The position of the feed point can be estimated as following

\[ L_0 = L_{\text{eff}} \left( I - \frac{I}{\sqrt{\varepsilon}} \right) \] (5)

According to the above Equs. (1)–(5), we can estimate that the patch is in a diamond shape with the length on Y axis being 37.26mm and on X axis being 30.22mm and the feeding point is 7.50mm away from the patch center. In order to achieve multiband characteristic, a rectangular slot is made in the center of the patch and it is then nested by using the similar structure to form the fractal morphology. Due to the reduced size of the radiation patch by the rectangular slot, the center frequency of the antenna will shift to the higher frequency. Thus, we appropriately adjust the patch size both in X direction and Y direction to maintain the center frequency unchanged.

3. RADIATION PROPERTIES OF THE SEMI-FRACTAL ANTENNA
We investigate the influence of the patch size on the center frequency of the fractal antenna. Firstly, the length \( L_1 \) of the antenna is fixed at 37.26mm and the feeding point is on Y axis, fixed at 7.50mm away from the center of the patch. As illustrated in Fig. 2, with the increase of the width \( L_2 \), the diamond angle \( \alpha \) becomes larger and the center frequency of the antenna gradually shifts to lower frequency with quite large return loss.

This is because the radiation current flows mainly along the two adjacent edges of the angle \( \alpha \). The larger the angle \( \alpha \) is, the longer the resonance wavelength, or the lower the resonance frequency of the antenna will be. In Fig.2 (b), the width of the antenna remains at 30.22mm and the feeding point is also fixed, the multiband characteristic and the resonant frequencies of the antenna remain almost unchanged. With the increase of \( L_1 \), the return loss decreases gradually, except at \( L_1=53.26 \)mm, which is due to a better input impedance match of the antenna. After optimization, we finally determine the dimensions of the antenna with \( L_1=52.99 \)mm, \( L_2=39.99 \)mm and the feeding point being on Y axis, 7.50mm away from the patch center.

In order to achieve the impedance matching and circular polarization characteristics of the antenna, a symmetrical apex cutting is made on the X axis of the patch based on the above size, as illustrated in Fig. 3.

![Fig.2. S11 varies with the width \( L_2 \) as well as the length \( L_1 \)](image)
As can be seen from Fig.4, the antenna has multiband characteristic, which can be used at 2.45GHz, 4.80GHz and 8.70GHz frequency bands. The influence of the apex cutting on the resonant frequency of the antenna is small, however, with the increase of cutting size, the return loss firstly decreases until cut=18mm, then it increases again. This is because the apex cutting makes the patch edge become two obtuse angles and thus the surface current can flow in a relatively smooth route to realize a better impedance matching, reducing the return loss. However, when the cutting size further increases, it reduces the efficiency of the end radiation mode of the antenna, so the return loss increases again. When the cut=18mm, the gain of the antenna can reach 6.95dBi when working at 2.45GHz and the radiation pattern is good, as illustrated in Fig.5.

4. SUMMARY

In this paper, a new type of semi-fractal antenna is designed for the application of RFID technology. Compared with traditional RFID antennas, it works at much higher frequencies in the UHF band, which is suitable for the development in future RFID technology. The antenna possesses a multiband property, which works at 2.45GHz, 4.80GHz as well as 8.70GHz. Moreover, the gain of the antenna for working at 2.45 GHz is as high as 6.95dBi, which can effectively improve the identification distance in RFID industry. These characteristics manifest the antenna a great potential applications in wireless communication system, especially in RFID technology.
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