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A New UHF Compact Circularly Polarized Tag Antenna Design

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Abstract

In order to solve the problem of miniaturization of tag antennas, a small circularly polarized tag antenna with UHF operating frequency was designed. The tag antenna adopts the design of the microstrip patch type. The cross-shaped slot and the circular slot on the radiating patch can reduce the antenna size and adjust the length of the slot to achieve the design goal of circular polarization. The dielectric substrate adopts a thickness of 1.6 mm FR4. Through the electromagnetic simulation software HFSS simulation, the -10dB bandwidth of the tag antenna is 53MHz (885-938MHz), which completely covers the Chinese UHF working frequency band, and the maximum identification distance of the tag antenna is calculated to be 2.62 meters. The research results show that the ultra-high frequency small circularly polarized tag antenna has good working performance and can be applied to warehouse logistics management on a large scale.

Keywords

Tag Antenna; Circular Polarization; Ultra-high Frequency; Microstrip Patch; Miniaturization.

1. Introduction

The progress of the Internet has brought online shopping into the fast lane, and more and more logistics industries have gradually developed and expanded. Among them, express delivery companies are developing fastest, and tens of thousands of packages need to be transported to all parts of the country. In order to facilitate the management and statistics of packages, labels are often attached to the packages for identification. Traditional two-dimensional codes and barcodes have problems such as short reading distance, slow recognition speed, and low sensitivity. In comparison, UHF RFID tags not only solve these problems, but also have the following advantages: they can penetrate glass, wood, plastic and other obstacles to read targets, and are less affected by harsh environments; they are fast and can be read. Recognize multiple targets at the same time, and can be recognized at a long distance; high reuse rate, large data memory capacity; high security, its content can be protected by a password, and the content is difficult to forge and change; it has diversified forms and is affected by objects when reading The shape and size are less restricted.

In recent years, with the continuous maturity of processing technology, the advantages of UHF RFID tags have become more and more obvious. The research of UHF tags mainly includes chip design, impedance matching theory research, and antenna structure design [1-6]. There are several commonly used design methods for miniaturization of tag antennas [7-10]:

(1) Serial connection and parallel connection of stubs: commonly used stubs include short-circuit metal plates, thin metal wires, pins, etc., load them between the radiating sheet and the metal grounding plate, and the potential at the grounding metal plate If it is zero, the mirroring effect expands the effective length of the tag antenna twice, so the actual size of the antenna only needs half of the theoretically calculated value. Place a short-circuit thin metal conductor next to the feed point

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of the planar inverted F antenna. The feed conductor and the short-circuit wire are coupled to each other, which increases the capacitance value of the antenna equivalent circuit and shifts the antenna resonance frequency center to a lower frequency, which indirectly reduces The overall size of the antenna. Serial connection and parallel connection of stubs make impedance matching more difficult, require high manufacturing and processing accuracy, and increase production costs. The stub loading technology has certain limitations and needs to be further improved.

(2) Fractal structure design: The antenna design is divided into shapes, which is conducive to reducing the size of the antenna, precisely because the fractal structure has the characteristics of fractal dimensions. Secondly, the current distribution of the fractal structure has self-similarity, which increases the transmit power and impedance width of the antenna. In a limited space, the fractal structure occupies less space, the dimension of the fractal antenna increases, and the total length of the antenna increases, which is conducive to the realization of multi-band characteristics. An antenna designed with a fractal structure requires high manufacturing and processing precision and relatively high cost.

(3) Slotting technology: Slot holes are dug on the antenna's radiating sheet or grounded metal plate. The length and width of the slot holes can be changed. After slotting, the surface current flow path increases in the metal sheet. That is equivalent to increasing the inductance in its equivalent circuit. The length of the antenna produces equivalent capacitance. The increase in the inductance of the antenna after slotting can offset the capacitance of the antenna itself, thereby reducing the length of the antenna, reducing the overall size, and achieving a small size.

A circularly polarized wave is composed of two linearly polarized waves with the same amplitude and a phase difference of 90 degrees, and orthogonal in space and time. Any circularly polarized wave can be decomposed into two linearly polarized waves. . Therefore, in order to realize the circular polarization of the tag antenna, the feeding point needs to excite two linearly polarized waves of equal amplitude, orthogonal, and phase difference equal to 90 degrees. There are four commonly used circular polarization design methods [11-12], namely:

(1) Single-feed point method: In theory, the cavity model is often used to analyze the point-feed point method. Radiation patches are generally circular or rectangular with regular shapes. The feeding point is usually placed in the positive direction of the center of the radiating patch or at a position offset by 45 degrees forward and backward. The feeding point is kept at a certain distance from the center point and placed on the radiating metal. Circular polarization is achieved by slotting, cutting corners, and adding short wires on the sheet. The circular polarization antenna designed by this method is small in size and simple in structure, but it will result in a narrow band of the tag antenna.

(2) Multi-feed point method: Compared with the single-feed method, the multi-feed method increases the number of feed points. Generally, two feed points are used. The radiating metal patch is generally circular or rectangular. By appropriately adjusting the positions of the two feeding points, multiple linearly polarized waves are excited at the feeding points, so that the polarized waves generated by them can be superimposed to meet the requirements of equal amplitude, orthogonality, and phase difference of 90 degrees. It can form circular polarization.

(3) Microstrip array method: use multiple identical microstrip structures to form an array, and each microstrip structure may have multiple different polarized waves. When they are superimposed on each other, the phase difference is 90 degrees. When the constant amplitude orthogonal linearly polarized wave, circular polarization can be formed. Because the phase center frequency of each linearly polarized wave is different, the axial ratio of the circularly polarized wave generated by superposition is different at each angle. Generally, the axial ratio directly above the antenna is closest to the ideal circular polarization, while the performance of circular polarization at other angles is not good, and it needs to be repeatedly debugged in the simulation design to meet the requirements.

(4) Curved surface structure method: The curved surface structure method is to use the compact structure of irregular smooth surface to achieve the design goal of circular polarization. The feeding point and absorbing load are respectively placed on both ends of the curved surface, and the electric

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wave forms a traveling wave on the curved surface. When the phase of the generated traveling wave is 2π, the circular traveling wave antenna can achieve circular polarization, and the frequency band of this type of tag antenna is relatively wide. However, due to the irregular shape of this antenna, it cannot be analyzed in accordance with conventional methods, the theoretical derivation is more complicated, and the processing accuracy is high, so it is rarely applied in practice and in-depth research.

2. Antenna structure design

The structure and size of the antenna are shown in Figure 1. The dielectric substrate is FR4, the thickness H is 1.6mm, the relative dielectric constant is 4.4, and the loss tangent angle is 0.02; the radius of the circular radiating patch is R2=28mm. The loop feeder and the metal grounding plate are connected by short-circuit copper holes. The label chip adopts Alien H3, the sensitivity is -18dBm, and the impedance value at the resonance frequency of 915MHz is 27-j201Ω. In order to make the chip and antenna conjugate matching, the impedance value of the antenna at the resonant frequency of 915MHz should be 27+j201Ω.

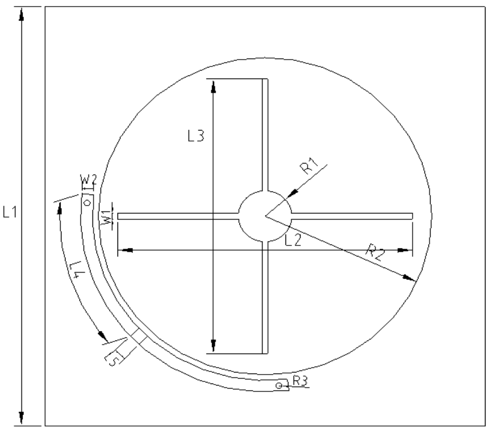

Figure 1. Tag antenna structure

Table 1. Tag antenna size (unit: mm)

L1	L2	L3	L4	L5	W1	W2	R1	R2	R3
74	49.5	48.5	28.2	2	1	2	4.5	28	0.5

Two slits and circular slits of different sizes are opened on the radiation patch, the length and width of the slits are adjusted, and the current path is changed to realize circular polarization. The small circularly polarized tag antenna uses a coupled feed form. The loop feeder is connected to the metal ground plate of the antenna with a short-circuit copper pillar, and the chip is connected to the feeder. The advantage is that the antenna impedance value can be changed by the circular slot radius R1, the slot length L2, L3, etc., so as to adjust the antenna resonance frequency and improve the matching degree between the antenna and the chip.

3. Simulation results

In order to accurately obtain the various parameter characteristics of the designed small circularly polarized tag antenna, HFSS software is used for simulation testing. In Figure 2(a), keep L3 and R1 unchanged, and change the value of L2. As L2 increases, the antenna impedance value decreases; in (b), keep L2 and R1 unchanged, and change the value of L3, With the increase of L3, the antenna impedance value decreases; in (c), keep L2, L3, change the value of R1, as R1 increases, the antenna impedance value first decreases and then increases. After optimization, it is determined that L1=49.5mm, L1=48.5mm, and R1=4.5mm. The optimized antenna impedance curve is in (d). At the resonance frequency of 915MHz, the antenna impedance value is 25.3+j202.34Ω.

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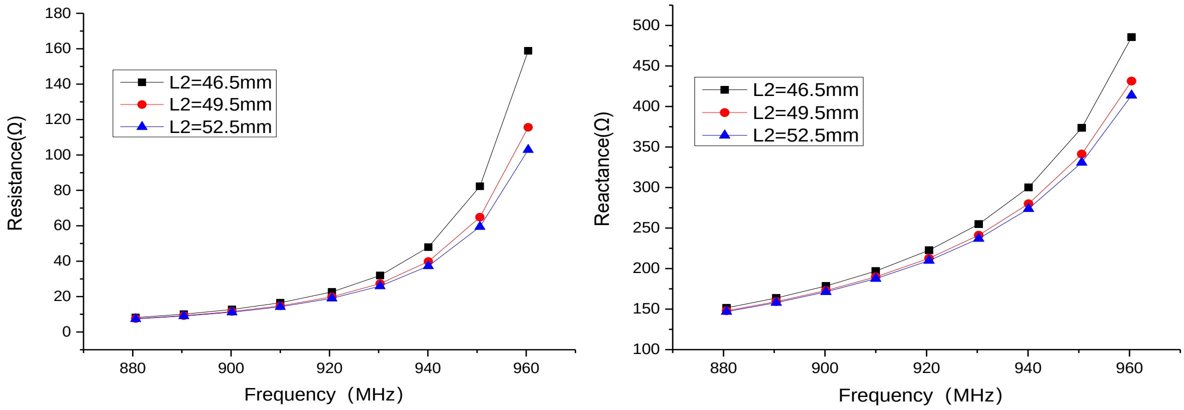
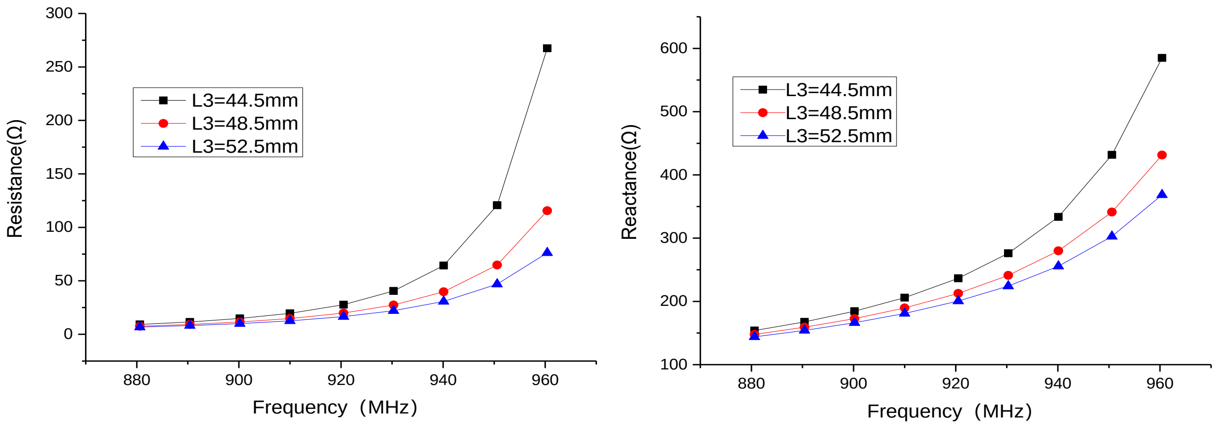
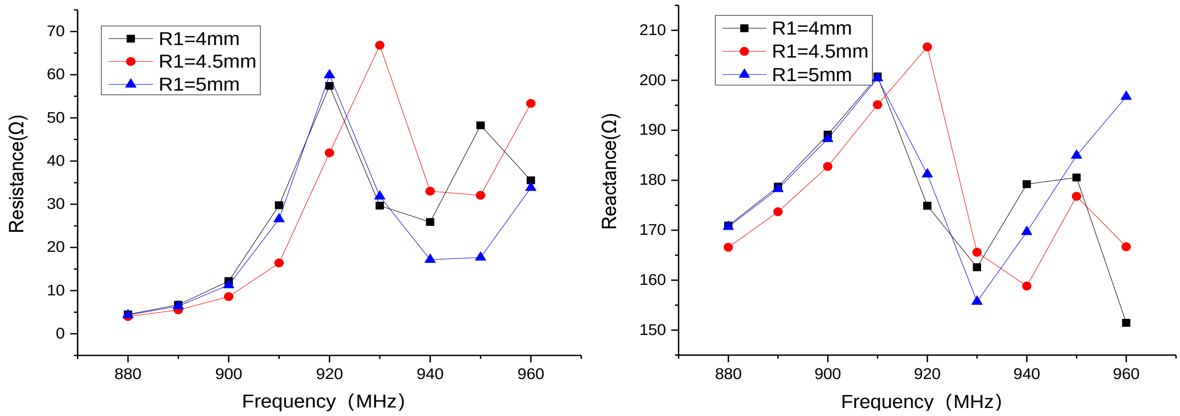


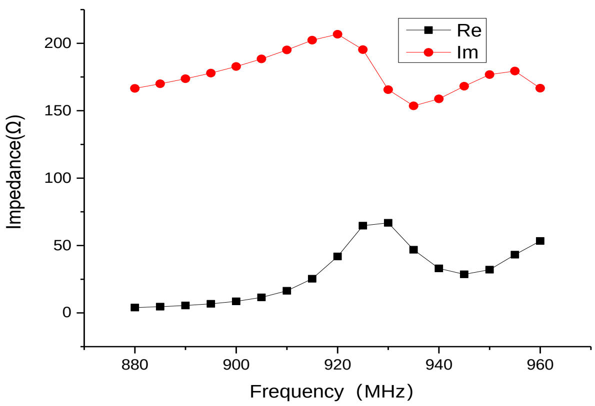
(a)



(b)



(c)



(d)

Figure 2. (a), (b), (c), (d) antenna impedance curve

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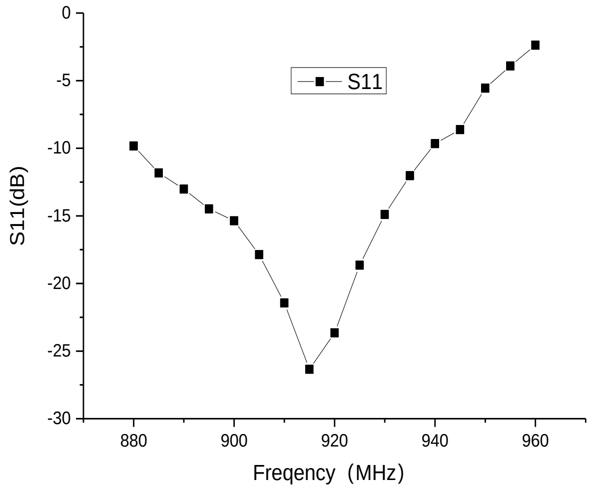

Figure 3. S11 curve

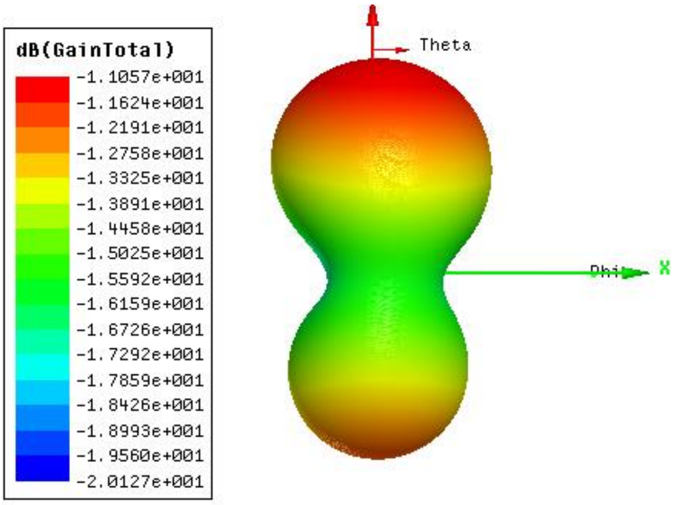

Figure 4. 3D Gain

Figure 3 shows the S11 curve of the antenna reflection coefficient after HFSS simulation. It can be seen from the figure that at the resonance frequency center f=915MHz, the reflection coefficient of the tag antenna in the free space is -26.5dB. The -10dB frequency range is 885MHz-938MHz (53MHz), which completely covers the UHF frequency range (920MHz-925MHz) specified by China. Figure 4 shows the 3D gain of the antenna at different angles, and the maximum gain is -11.057dB respectively.

The formula for calculating the transmission distance by Fries:

$$R = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP \bullet G_r \bullet \tau}{P_{th}}} \tag{1}$$

Among them, EIRP stands for equivalent omnidirectional radiated power. The Chinese standard stipulates that it is 33dBm, Gr is the gain of the receiving antenna, τ is the transmission efficiency, and Pth is the read sensitivity of the chip. Taking the measured data into the formula to calculate, the maximum identification distance of the tag antenna is 2.62m. When the tag antenna is installed on a 400*400 mm^2 metal plate, the gain is about 4dB decibels higher than that of the antenna installed in free space, and the maximum identification distance of the tag antenna is 5.12m. This increase in gain may be due to the superposition of reflections and radiation from the metal plane. From the above results, it is further proved that the proposed tag antenna is strongly circularly polarized, and when the proposed tag is mounted on a metal surface, the reading range can be greatly increased.

4. Conclusion

In this paper, a small circularly polarized tag antenna is designed, and the structure diagram is drawn through the HFSS software, and the simulation operation is used to obtain the reflection coefficient, gain and other parameters, and calculate the recognition distance. By changing the radius of the circular slot R1, the length of the slot L2, L3, etc., the impedance value of the antenna is changed, so that the matching degree of the tag is continuously improved, and an antenna that meets the requirements is designed. In the end, the antenna parameters have good performance, which can be applied to express freight management.

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