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The design and simulation of UHF RFID microstrip antenna

Xiangqun Chen[1], Rui Huang[1], Liman Shen[1], Liping Liu [1], Dezhi Xiong[1], Xiangqi Xiao[1], Mouhai Liu[1], Xu Renheng[2]

[1](State Grid Hunan Power Supply Service Center(Metrology Center)，Changsha 41000，China)

[2](Harbin Research Institute of Electrical Instrumentation, Harbin 150028, China)

Abstract: At present, China has delineated UHF RFID communicating frequency range which is 840 ~ 845 MHz and 920 ~ 925 MHz, but most UHF microstrip antenna don't carry out this standard, that leads to radio frequency pollution. In order to solve the problems above, a method combining theory and simulation is adopted. Combining with a new ceramic material, a 925.5 MHz RFID microstrip antenna is designed, which is optimized and simulated by HFSS software. The results show that the VSWR of this RFID microstrip antenna is relatively small in the vicinity of 922.5 MHz, the gain is 2.1 dBi, which can be widely used in China's UHF RFID communicating equipments.

1. Instructions

With the development of Internet of Things technology, RFID communication has been widely applied to daily life.[1] Internationally, RFID communication is mainly divided into such four frequency bands as low frequency (125 ~ 134 KHz), high frequency (13.56 MHz), ultra high frequency (860 ~ 960 MHz) and microwave (2.45 GHz and above) [2, 3].

Wherein,low-frequency and high-frequency RFID communications are characterized by strong penetrating ability, slow transmission speed and short operating range, both of which are generally applied in access control security system[4], library management[5], electronic consumption[6] and other areas. Microwave RFID communication generally takes an active approach, characterized by the short operating range, suitable for road tolls, vehicle management[7] and other fields. Comparatively, ultra-high-frequency RFID communication has been widely used in warehouse management[8] logistics tracking[9],and industrial production[10]and the like thanks to its characters like fast speed and far operating range.

Early in 2007, the Ministry of Industry and Information Technology released, under the international standards, the *Trial Provisions on the Application of Radio Frequency Identification (RFID) Technology in the 800 / 900MHz Frequency Band*, which clearly defines that China's UHF RFID frequency band range fall into 840 ~ 845 MHz and 920 ~ 925 MHz, requires the radio management agencies at all levels to strengthen the management of the use of RFID equipment of above-mentioned frequency bands, and timely deal with radio interference to ensure that the smooth application of RFID technology with such frequency bands [11].

As an important part of UHF RFID communication, the reader antenna has been indispensable.However, nowadays, most domestic UHF RFID antennas still adopt the foreign standards (center frequency 915 MHz)[12].For example, the North American standard with a frequency ranging from 902 MHz to 928 MHz partially overlaps with other communications including domestic GSM (uplink frequency bands from 885 MHz to 909 MHz) in the frequency band, which may easily cause radio interference. Therefore, it's particularly vital to design UHF RFID antennas whose center frequencies are in line with China's provisions.

In this paper, a small UHF microstrip antenna with a center frequency of 920-925 MHz is designed based on the new ceramic materials and further simulated and optimized with HFSS simulation software.

2. Antenna design

A microstrip antenna is fabricated with a metal radiating patch bonded to one side of a dielectric substrate which is much thinner than the operating wavelength, and a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. The metal radiating patch may be designed of various shapes as per different requirements. Starting from the first microstrip antenna proposed by G.A. Deschamps in 1953, the microstrip antenna has been widely applied to various wireless communications due to its advantages like light weight, small size and easy manufacture[13].

In this paper, the microstrip antenna designed first adopts a new ceramic material with its dielectric constant ε_r of 22.3 and thickness h of 4.7 mm. The logistics tracking is set 920-925 MHz and the center frequency f is 922.5 MHz. Through Eq. 1, the high-efficiency radiation patch width w may be obtained, i.e.:

$$w = \frac{c}{2f}\left(\frac{\varepsilon_r + 1}{2}\right)^{\frac{1}{2}} \tag{1}$$

Wherein, c is the speed of light in the vacuum. Taking into account the edge effect, the actual length of the radiating element L is:

$$L = \frac{c}{f\sqrt{\varepsilon_e}} - 2\Delta L \tag{2}$$

Wherein, ε_e is the effective dielectric constant ΔL is the equivalent length of radiation slot, which can be calculated using Eq. (3) and Eq. (4), respectively:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{\frac{1}{2}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_e + 0.3)(w/h + 0.264)}{(\varepsilon_e - 0.258)(w/h + 0.8)} \tag{4}$$

In the impedance matching, a coaxial feed method is adopted. When the feed point is at the edge of the radiating patch (i.e. x = ± L / 2, y = ± L / 2), the input impedance is at its highest (typically 100-400 Ω) to activate the TM_{10} operating mode. When the feed point is at the geometric centre point (i.e. x=0 and y=0) of the radiating patch, the input impedance is 0, when it's impossible to activate the TM_{10} operating mode. When the feed point deviates from the center along the coordinate axis,it will activate the TM_{10} operating mode,and increase the antenna's cross-polarized radiation.Normally, the standard input impedance of the antenna is required to be 50Ω and the position L_1 of the feed point at this time can be approximated by the Eq. (5).

$$L_1 = \frac{L}{2\sqrt{\varepsilon_e}} \tag{5}$$

Given the requirements by the circular polarization of the antenna, a 45° chamfering process is properly performed at the diagonal positions of the radiating patch, so that the antenna has a good response when receiving left-handed and right-handed signals.

3. Modeling and simulation

HFSS (High Frequency Structure Simulator) is a software tool for 3D full-wave electromagnetic field simulation developed by the America-based Ansoft. By utilizing the Tangential-Vector Finite-Element Method (TVFEM), HFSS can solve any electromagnetic field distribution of any 3D radio frequency and microwave devices, and calculate the losses resulting from materials and radiation[14, 15]. Meanwhile, it can directly obtain a variety of results, including the characteristic impedance of the simulation model, S-parameters and electromagnetic fields, radiation fields, specific absorption rate[16]. It's widely used in the design of devices like antennas, feeders, filters and isolators and the computing of issues including electromagnetic compatibility, electromagnetic interference, antenna layout and mutual coupling[17].

According to the calculation results of the antenna design in the previous section, a simulation model is built in the HFSS simulation software, as shown in Figure 1.

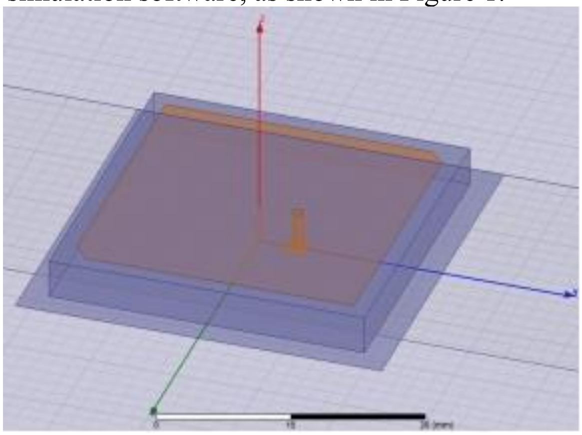

Figure 1 Microstrip antenna simulation model

When setting the radiation boundary conditions, it's normally required that the radiation boundary surface should be 1/4 the operating wavelength away from the radiator. From Eq. (6), we can derive that λ=325 mm, i.e. 1/4 λ =81.3 mm.

$$\lambda = \frac{c}{r} \tag{6}$$

Set the solution frequency to 922.5 MHz and the scan frequency range from 800 to 1100 MHz for simulation analysis. According to the simulation results, adjust the position of the feed point, which means to change the size of L_1. When L1 moves to the position of 4.55 mm, the input impedance at the 922.5 MHz frequency is approximately (49.46 + j1.81) Ω, which is the closest to the standard requirement of 50 Ω, as shown in Figure 2.

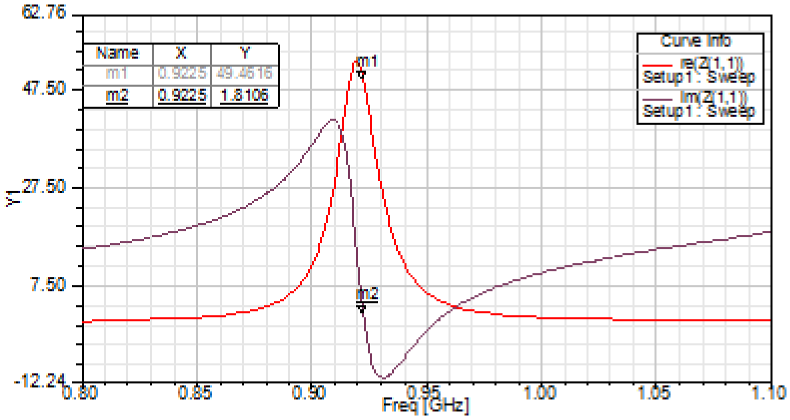

Figure 2 Change curve of re and im along with the frequency when L_1 is 4.55mm

Draw an S_{11} Sweep Frequency Response Analysis (SFRA) Curve as shown in Figure 3.At the 922.5 MHz center working frequency, the S11 is -34.43 dB, smaller than -30 dB, which indicates that the antenna achieves the best impedance matching. Similarly, a good matching result is obtained on the antenna's Smith chart, as shown in Figure 4.

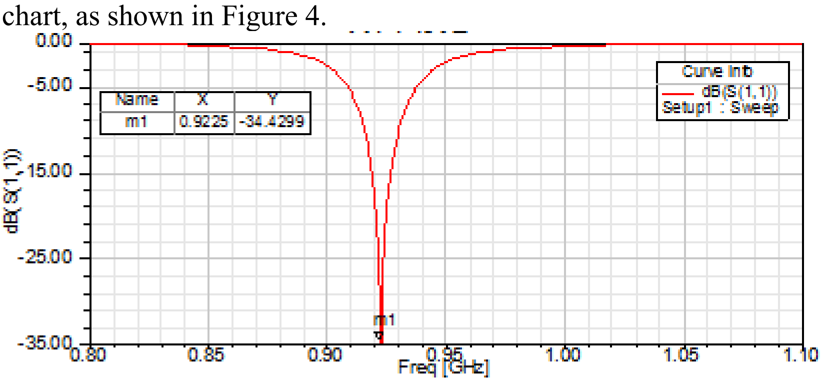

Figure 3 S_{11} Sweep Frequency Response Analysis (SFRA) Curve when L_1 is 4.55mm

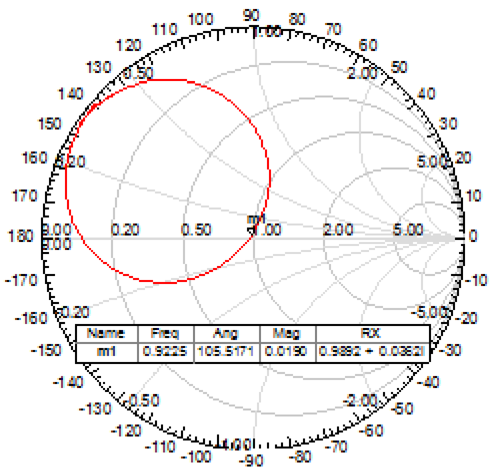

Figure 4 Smith chart

Draw a Voltage Standing Wave Ratio (VSWR) Curve as shown in Figure 5.When VSWR<1.5, the bandwidth of this antenna is about 8.5 MHz. The gain direction of the antenna is shown in Figure 6, where it can be seen that the maximum radiation direction is directly above the radiating patch with a maximum gain of 2.1 dBi.

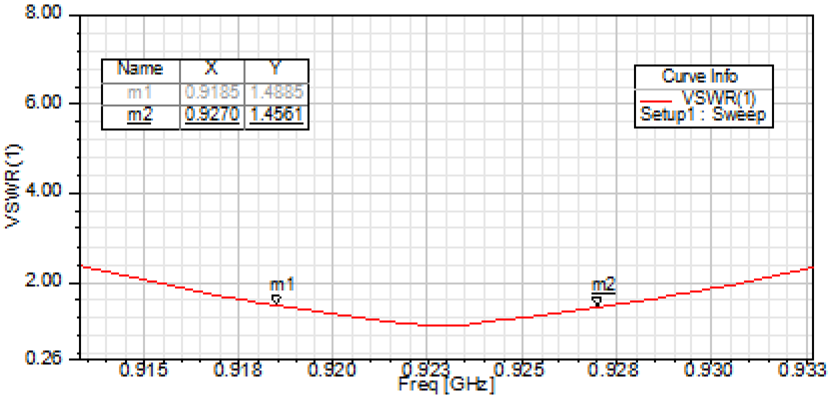

Figure 5 VSWR Curve

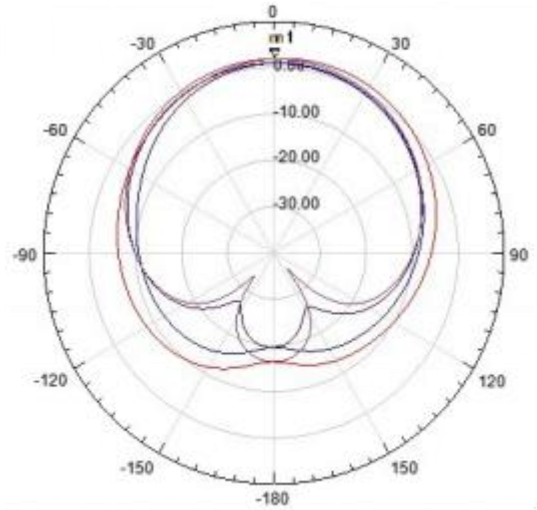

Figure 6 Antenna gain pattern

4. Conclusion

In this paper, a UHF RFID microstrip antenna is designed with new ceramic materials by combining the domestic standards of RFID communication and actual needs; and the HFSS software is used for modeling and simulation. The results show that the center frequency of the antenna is 922.5 MHz, S11 is -34.43 dB, and the impedance is about (49.46 + j1.81) Ω; and the bandwidth is 8.5 MHz and the gain is 2.1 dBi when the VSWR is less than 1.5. The antenna conforms to China's UHF requirements for RFID antennas, and can be widely used in UHF RFID reader/writer devices. Therefore, it boasts broad prospects for popularization and application.

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