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A Design of High Gain RFID Label Antenna with Anti-Interference of Mobile Communication Channel

Ouyang Guojun [1+]

[1]Guangdong AIB Polytechnic Department of Computer, Guangzhou, China 510507

Abstract. This thesis analyzes the IT device assets management environment, and requires that the label antenna of the RFID system shall be metal resistant, anti-absorbing by human body and mobile communication terminal interference resistant. The Chinese UHF RFID channels are 840-845MHz and 920-925MHz, which is near to the mobile communication CDMA800 and GSM channels, therefore, it will be easily interfered by the mobile communication system, thus increasing the increase of demodulation error rate of the RFID label. Via the analysis on the formation mechanism of mobile communication system to RFID interference, this thesis proposes the UHF RFID label antenna design method which is capable of resisting the interference from the mobile communication terminal, is derived the formula of calculating dielectric substrate thickness h, after repeated experiment with HFSS, the reasonable dielectric substrate relative dielectric constant ε_r and loss tangent $\tan\delta$ values are confirmed, thus designing the RFID label antenna with anti-interference of mobile communication channel and high gain. It is shown from simulation results that the return loss S_{11} value of RFID channel is less than -10dB, the return loss S_{11} of CDMA800 and GSM channels are over -10dB, the voltage standing-wave ratio VSWR value of mobile communication channel is over 2, the voltage standing-wave ratio VSWR value of RFID channel is less than 2, the maximum gain of antenna of the RFID label reaches 7.28*dBi* and the maximum theoretical reading distance is 17.66*m*..

Keywords: RFID label; label antenna; mobile communication interference; anti-interference; UHF channel; high gain

1. Introduction

Currently, as the popularization and application of IT technology, IT assets have become the core assets of administrations, enterprises and institutions, and strict management should be conducted for such assets, therefore, the fixed assets management system which is based on the RFID label technology has gained wide application [1].

After the survey on the application of RFID assets management system, it is discovered that reasonable selection of RFID label antenna performance assumes enormous importance for the success of the project. For the system under good working, most RFID label antennas are specially designed or selected according to the onsite environment with the consideration on the reflection, refraction, diffraction, absorption or attenuation of the application environment of the RFID system.

IT assets mostly refer to the computers and network devices in the office and laboratory. The housing of the IT device is metal, and the management cycles exceeds 5 years, IT assets features scattered working sites, strong mobility, more people and objects in the working site and popularization of mobile communication terminal. The most serious issues occurred in the RFID system application of IT assets management are the metal reflection, absorption of human body to electromagnetic wave and the electromagnetic spurious interference of UHF channel mobile communication system. The influences of metal and human body on label performance is shown in Table 1[2], the electromagnetic spurious interference caused by the mobile

+ Corresponding author. Tel.: +86 02085230273; fax: +86 02085230273.
E-mail address: gzoygj@163.com.

communication system reduces the reading distance of reader and drops the signal-to-noise ratio of the label chip input terminal [3]. Therefore, the destructive interference of metal must be eliminated and active interference must be introduced during the design and selection of RFID label antenna for IT device assets management; with consideration on the absorption of human body, it should have adequate gain without harm to people. In addition, in order to operate the remote assets management remotely via the Internet of Things, fixed reader is mostly adopted for the RFID system, analyzing from the space of the office and laboratory, the distance between the reader and the label is over 8*m*. Basing on the above factors, the design of RFID label antenna for IT device assets management shall meet the following requirements: (1) the label is inactive and ultrahigh frequency (UHF); (2) the label has good metal resistance without the influence from metal boundary conditions; (3) the label shall have good directionality, it is better to have omnidirectional characteristics at the upper hemisphere of the metal surface; (4) the label has the function of resisting interference from mobile communication system; (5) the label shall have high gain with far reading distance; (6) the label has low cost, simple manufacturing process, and shall be easy for mass production.

Table 1. Influence of metal and human body to the RFID system

Metal	
Label is behind the metal	It can't work, the metal reflect the wave.
Label is pasted on the metal	Not sure, it is related with the metal.
Label is very near (several millimeters) to the metal	It is possible that the label can work. The metal generates reflection wave, the active influence is that it increases the antenna gain as the reflector, the destructive influence is that it produces black hole and the signal is cut.
Human body	
Label behind the human body	Strong absorption (about 80% of human body is water), the label work badly or can't work
Hand is put on the label	Strong absorption, the label can't work normally
Label several centimeters (3-5cm) in front of human body	Absorption, but the label can work normally

Basing on the requirements of the IT device assets management environment that the label antenna of the RFID system shall be metal resistant, resisting absorption by human body and mobile communication terminal interference resistant, in accordance with the Chinese 800/900MHz standard regulated in GB/T 29768-2013, the coaxial feed rectangular structure microstrip antenna is adopted as the prototype to design a kind of metal resistant dual-frequency microstrip antenna. The design method of mobile communication terminal interference resistant is put forward, and the corresponding calculation formula of dielectric substrate thickness h is derived. Via reasonable selection of dielectric substrate relative dielectric constant ε_r and loss tangent $\tan\delta$ value, the maximum gain of antenna reaches 7.28*dBi*, *the* theoretical valuation of maximum reading distance of the label reaches 17.66*m*. The designed RFID label antenna meets the special requirements of the IT device assets management environment.

2. Structure and Selection of Label Antenna Model

The common metal resistant RFID label antenna structures in engineering include microstrip antenna and planar inverted-F antenna (PIFA) [4]. Metal surface is adopted as the grounding plane of the microstrip antenna to design the metal resistant label antenna, the effective length of the microstrip antenna shall be 1/2 of its working frequency wavelength. The planar inverted-F antenna (PIFA) is equipped with the metal ground plane to achieve the function of metal resistance, the antenna has small size, and the effective length is 1/4 of the working frequency wavelength. Listed in literature [5], two coupled parasitic patches are installed for the microstrip structure to excite the new resonant mode, improve the bandwidth to 148 MHz, which has covered the channel of all ultrahigh frequency RFID systems, the reading and writing distance of the antenna is about 4m. Microstrip antenna with balanced double feed structure is adopted in literature [6], the label working performance expresses satisfied consistency in different physical environments, 3dB bandwidth is 8.2MHz, it can't cover the 800/900MHz channel, the reading and writing distance is about 10m. PIFA structure is adopted for designing in literature [7-8], the reading and writing distance is less than 3m. It is known from the above analysis, the area of the microstrip antenna is bigger than PIFA, and the performance in reading and writing distance is better than PIFA. Since the superficial area of computers and network devices meets: $L_{GND} \geq L + 6h$, $W_{GND} \geq W + 6h$ (L_{GND} is the surface length of the device, W_{GND} is the surface width of the device, L is the label length, W is the label width, and his the dielectric layer thickness), therefore, RFID label for IT assets management doesn't have high requirement on size, and microstrip antenna is suitable.

Since the input impedance of the antenna doesn't equal to the impedance of common 50 Ω transmission cable, therefore, matching is required, the matching may be operated by suitable feed position. The microstrip antenna has diversified modes such as microstrip line feed, coaxial line feed, coupled feed and gap feed, microstrip line feed and coaxial line feed are frequently used. Radiation characteristics is also affected by the feed mode and feed position [9]. Microstrip feed features simple manufacturing, but the feeder itself has radiation and will interfere the antenna pattern and drop the gain. The feed point of coaxial line feed may be selected at any position in the patch, which can avoid the influence to the antenna radiation, but it will cause inductance and affect the input impedance of the antenna.

Through overall consideration, coaxial feed microstrip antenna structure is adopted as the prototype for this design.

The basic structure of label antenna composes of three parts: radiation patch, dielectric substrate and coaxial feeder, shown in Fig. 1. Where, dielectric substrate is the reflecting surface, radiation patch is the sheet metal parallel to the floor, and the feeder is sued for signal transmission, dual-frequency is achieved through reasonable position setting of coaxial feed points.

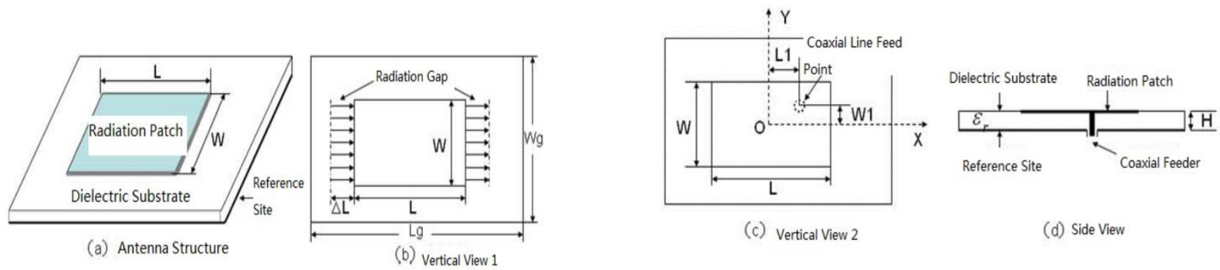

Fig. 1: Structure of Label Antenna

3. Design Indices of Label Antenna

The RFID label antenna designed in this thesis abides by the "Information Technology - Radio frequency Identification - Air interface Protocol at $800/900MHz$" (GB/T 29768-2013) standard, the design indices are:

1) Working center frequency 842.5MHz and 922.5MHz;

2) The anti-interference performance of the label antenna: the reflection coefficient of this system $S_{11} \leq -20dB(VSWR \leq 2.0)$, different system reflection coefficient $S_{11} \geq -10dB(VSWR \leq 2.0)$;

3) Maximum gain $G_{ant} \geq 6dB$;

4) Maximum theoretical distance $r_{\max} \geq 10m$.

4. Analysis on the Formation of Mobile Communication System Terminal Interference

4.1. Working principle of UHF RFID

UHF RFID system adopts the working mode of electromagnetic wave transmission coupling, the principle is shown in Fig. 2, the working process includes two parts.

1) The reader antenna sends the query signal to the RFID label, which includes the instructions such as Energy, Select and Query. RFID label receives the query signal from the reader via label antenna, converts the energy into voltage to supply power for the label chip, when the voltage is high enough, the label chip was enabled and starts working. After enabled, the label chip receives the query instructions from the reader, and acts accordingly.

2) The reader and label responds and communicates according to the protocol. The reader sends the continuous wave to provide energy for the enabled label. The enabled label respond the reader within the time of continuous wave via back scatter modulation method, after receiving the acknowledgement signal, the reader sends the confirmation instruction and continuous wave, the label sends the data to the reader within the time of continuous wave, after receiving the data, the reader sends the confirmation instruction to the label.

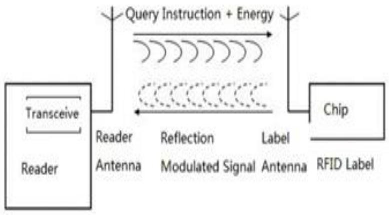

Fig. 2: Working Principle of UHF RFID System

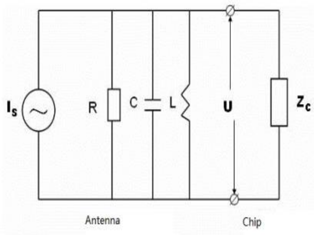

Fig. 3: Equivalent Circuit Model of Label

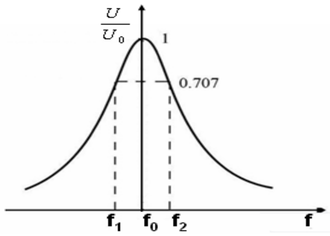

Fig. 4: Passband Distribution Diagram of Antenna Circuit

4.2. Equivalent circuit model of label

The microstrip antenna equivalent is parallel circuit [10], in Fig. 3, the query signal of reader induces the current I_S in the antenna, Z_C is the chip input impedance. The admittance of antenna circuit is:

$$Y = G + j(\omega C - 1/\omega L) \tag{1}$$

Then, the terminal voltage U in chip impedance is:

$$U = \frac{I}{Y} = \frac{I}{1/R + j(\omega C - 1/\omega L)} \tag{2}$$

When $\omega C = 1/\omega L$, which means parallel resonance occurs, the resonant frequency is

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{3}$$

Then, U gets the maximum value U_0. The passband distribution diagram of antenna circuit is shown in Fig. 4, the bandwidth of antenna circuit is:

$$BW = f2 - f1 \tag{4}$$

It means the frequency selectivity of antenna, which means that signal will possibly enable the chip within this frequency range, according to the Chinese regulation, the stray emission limit at the antenna port within the UHF RFID 806MHz-960MHz shall be -52dBm.

4.3. Mobile communication and RFID channel division in Chinese UHF channel

Table 2. Mobile Communication and RFID Channel Division in Chinese UHF Channel

CDMA800 Uplink	RFID	CDMA800 Downlink	GSM Uplink	RFID	GSM Downlink
825-835MHz	840-845MHz	870-880MHz	885-915MHz	920-925MHz	930-960MHz

4.4. Interference of mobile communication terminal to RFID label

It is seen from Table 2, the difference between CDMA800 uplink channel and RFID 840-845MHz channel, the GSM uplink and downlink channel and RFID 920-925MHz channel is 5MHz, which may easily produce intermodulation interference and intermodulation interference [11], if the frequency selection performance of UHF RFID label antenna is not ideal, the electromagnetic wave frequency transmitted from the mobile communication terminal is in the resonant bandwidth of label antenna, then it will be induced by the label antenna and enable the chip, the electromagnetic wave transmitted from the mobile communication terminal is coupled to the label chip, since the information carried in such electromagnetic wave is random, the coding mode is also different from the UHF RFID system signal, therefore, the signal-to-noise ratio of the label chip input terminal will be dropped, and the demodulation error rate of the RFID label will be increased [3].

5. Design Method of Mobile Communication Terminal Interference Resistant

For convenient analysis, the Chinese UHF RFID channel and mobile communication UHF channel range shown in Table 2 are drawn into the UHF channel frequency classification chart, please refer to Fig. 5.

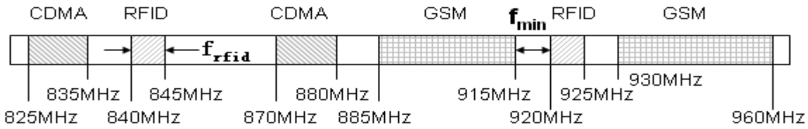

Fig. 5: Chinese UHF Channel Classification Chart

RFID channel width is set as f_{rfid}, the nearest distance between the UHF channel of CDMA and GSM and the RFID channel is set as $f_{\min}$. It is known from Diagram 4, to eliminate the influence of mobile communication frequency band to the label, the passband of antenna can't cover the mobile communication channel, therefore, the maximum bandwidth of antenna is:

$$BW = f_{rfid} + 2f_{\min} \tag{5}$$

$$\text{Since } BW = \frac{(VSWR - 1)}{Q_T\sqrt{VSWR}} \tag{6}$$

The total quality factor Q_T of antenna is expressed as:

$$\frac{1}{Q_T} = \frac{1}{Q_r} + \frac{1}{Q_d} + \frac{1}{Q_c}$$

where, Q_r, Q_d and Q_c are radiation, medium and conductor loss Q value respectively. Since the actual Q_d and Q_c are much higher than Q_r, the approximate calculation formula for Q_T is given in literature [12]:

$$Q_T \cong Q_r = \frac{c\sqrt{\varepsilon_{re}}}{4f_r h} \tag{7}$$

where, c is light velocity, ε_{re} is effective dielectric constant, f_r is resonant frequency, h is dielectric substrate thickness. According to formulas (5)-(7), the following can be obtained:

$$h = \frac{c(f_{rfid} + 2f_{\min})\sqrt{\varepsilon_{re}}\sqrt{VSWR}}{4f_r(VSWR - 1)} \tag{8}$$

ε_r value and loss tangent $\tan\delta$ value are selected reasonably, h value is calculated according to Formula (8), finish the selection of dielectric substrate material, the bandwidth of RFID label antenna won't cover the CDMA and GSM channel, which means that the return loss of the electromagnetic wave transmitted from mobile communication system in the antenna is $S11 > -10dB$, which won't enable the chip, the antenna has excellent performance in resisting mobile communication terminal interference.

6. Design of High Gain UHF RFID Label Antenna

6.1. Calculation of radiation patch parameters

The bigger radiation patch width W can benefit the frequency bandwidth, radiation efficiency and impedance matching, but it will generate higher harmonic mode and cause field distortion when the size is bigger than the value given in formula below.

$$W = \frac{c}{2f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2} \tag{9}$$

After confirming ε_r, h and W, effective dielectric constant ε_{re} can be figured out

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(1 + 12\frac{h}{W})^{-1/2} \tag{10}$$

Medium wavelength $\lambda_g = \dfrac{c}{fr\sqrt{\varepsilon_{re}}}$ (11)

Theoretically, radiation patch length L is set as $\lambda_g / 2$, for the influence from fringing field, when designing the size of L, $2\Delta L$ shall be subtracted from $\lambda_g / 2$, therefore:

$$\Delta L = 0.412h\frac{(\varepsilon_{re} + 0.3)(W/h + 0.264)}{(\varepsilon_{re} - 0.258)(W/h + 0.8)} \tag{12}$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{re}}} - 2\Delta L = 0.5\lambda_g - 2\Delta L \tag{13}$$

6.2. Confirmation of substrate size

The substrate size doesn't have obvious influence to the distribution of radiation field, for reducing antenna weight and installation area and dropping the cost, Lg and Wg shall be as small as possible.

Dielectric slab length $L_g = L + 0.2\lambda_g$ (14)

Dielectric slab width $W_g = W + 0.2\lambda_g$ (15)

6.3. Calculation of coaxial feeder positional parameters

The design of microstrip antenna for achieving dual-frequency working mode mainly composes of multilayer metal patch [13], lumped element loading (including shorting pin)[14], gap loading [15] and multimode orthogonal [16]. Multilayer metal patch and lumped element loading make the antenna structure complicated, gap loading is relatively simple for achieving dual-frequency but it will influence the frequency bandwidth and radiation efficiency. Multimode orthogonal method doesn't need to change the antenna structure, it excites the mutually orthogonal resonant modes which work in different frequencies via changing the feed position, thus achieving dual-frequency working mode. Multimode orthogonal method is adopted in this thesis for achieving dual-frequency.

For the rectangular microstrip radiation patch, the feed point is at the x-axis, it can excite TM_{10} mode, then, since the feed point is at the y direction central line of the radiation patch, it doesn't excite the $TM_{0n}(n = 1,3,5,\ldots\ldots)$ mode. The same, when the feed point is at the y-axis, it can excite TM_{01} mode, and doesn't excite $TM_{m0}(m = 1,3,5,\ldots\ldots)$ mode. If the feed point is set at near the diagonal of the patch (see Diagram 1 (c)), then it can simultaneously excite TM_{01} mode and TM_{10} mode, and can produce 50Ω input impedance, thus achieving the dual-frequency working of the antenna.

The formula of calculating the feed point position is shown in [17] :

$$L_1 = L(1 - 1/\sqrt{\xi_{re}(L)})/2 \tag{16}$$

where, $\xi_{re}(L) = (\varepsilon_r + 1)/2 + ((\varepsilon_r - 1)/2)(1 + 12h/L)^{-1/2}$

$$W_1 = W(1 - 1/\sqrt{\xi_{re}(W)})/2 \tag{17}$$

where, $\xi_{re}(W) = (\varepsilon_r + 1)/2 + ((\varepsilon_r - 1)/2)(1 + 12h/W)^{-1/2}$

7. Simulation Optimization of Label Antenna

7.1. Initial value of modeling

In order to drop the influence from mobile communication terminal, the resonant frequency shall be far from the CDMA and GSM channel as much as possible. When designing, the one with big resonant frequency value is defined as the first resonant frequency, the one with small resonant frequency value is the second resonant frequency, it can be seen from Diagram 5, the first resonant frequency of the antenna can be set as 922.5*MHz*, the second resonant frequency can be set as 842.5*MHz*, when calculating the initial parameter, the reference resonant frequency f_r is set as 922.5*MHz*, $f_{rfid} = 5MHz$, $f_{\min} = 5MHz$. Since the application site doesn't have special restraint to the antenna installation area or volumetric weight, but it has requirements on the gain of antenna, therefore, PTFE substrate material with $\varepsilon_r = 2.45$ and $\tan\delta$ =0.0018 is adopted. The radius of the coaxial feeder is 0.6*mm*. Data is substituted in formulas (5) -(17), the initial parameters of antenna design are shown in Table 3.

Table 3. Design variable name and simulation initial value

Parameter Name	Variable Naming	Simulation Initial Value
Dielectric substrate thickness	H	2.7*mm*
Dielectric substrate length	Lg	142.8*mm*
Dielectric substrate width	Wg	165.4*mm*
Radiation patch length	L0	101.1*mm*
Radiation patch width	W0	123.8*mm*
Coaxial feeder radius	Rfeed	0.6*mm*
Distance between coaxial feed point and x-axis	L1	17.2*mm*
Distance between coaxial feed point and y-axis	W1	21.7*mm*
1/4 working wavelength	Length	81*mm*
Radiation boundary length	AirBox_L	L0+2×Length
Radiation boundary width	AirBox_W	W0+2×Length
Radiation boundary height	AirBox_H	20*mm*+H+Length

7.2. Calculation and optimization of performance parameter

The antenna structure parameters are obtained via calculation, HFSS is adopted for modeling and parameters calculation. The return loss curve of antenna is shown in Diagram 6, the first resonant frequency value is $916.1MHz$, the second resonant frequency is $758MHz$, it can be seen that the difference between the first resonant frequency value and design index value is small, the difference between the second resonant frequency and the design index value is high.

Analyzing according to the above theory, the resonant frequency (the first resonant frequency) of TM_{01} model is mainly determined by the length L0 of radiation patch at the x-axis direction, the resonant frequency of TM_{10} model (the second resonant frequency) is mainly determined by the length W0 of radiation patch at the y-axis direction. It means that L0 value which is calculated according to Formula (13) is more accurate; The W0 value which is calculated according to Formula (9) is big, it is known from the above analysis, the maximum value of W0 is calculated according to Formula (9), during application, it shall be moderately dropped (dropping by about 10% after verifying via repeated experiments).

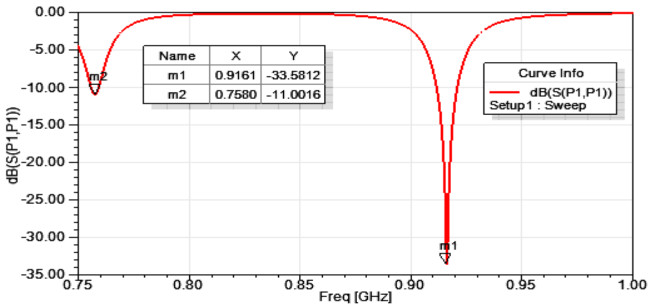

Fig. 6: S_{11} Analysis Results (L0=101.1*mm*, W0=123.8*mm*)

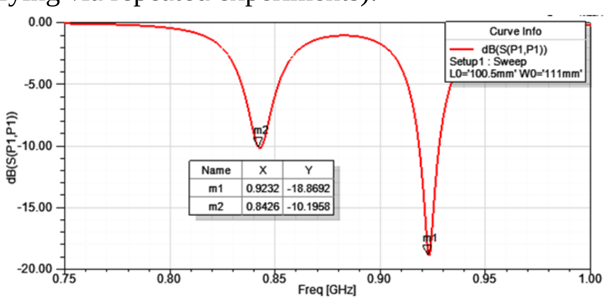

Fig. 7: S_{11} Analysis Results (L0=100.5*mm*,

W0=111.0*mm*)

Using the parameters sweep analysis function of HFSS, the length variables L0 and width W0 of radiation patch are added respectively for sweep calculation, then analyzing the relation of antenna resonant frequency with L0 and W0 respectively. It is seen from Fig. 6, when L0=101.1mm, the first resonant frequency is near 922.5MHz but less than 922.5MHz, therefore, L0 value range is set at 100mm-101.1mm and step size is set at 0.1mm for sweep analysis, the value 923.2MHz which is proximal to 922.5MHz is obtained when L0=100.5mm. Before W0 sweep analysis, according to the experience, W0 value is dropped by 10%, which means that 111.4 is adopted as the center of W0, plus or subtract about 5% in front and at behind, which means that the sweep analysis range is 105mm-118mm and step size is 2mm for analysis, then drop the range for the second sweep analysis, step size is set at 0.1mm for this time. Finally, one value 842.6MHz which is proximal to 842.5MHz is obtained when W0=111.0mm, please see Fig. 7.

It is shown from Fig. 7, after adjusting L0 and W0, the resonant frequency has basically reached the design target, but the S_{11} value at resonant frequency 923.2MHz is -18.87, the S_{11} value at resonant frequency 842.6MHz is -10.20, which fail to reach the goal.

It can improve the antenna performance [18] to adjust the feed point position and feeder core diameter. Since the adjustment of feed point position and feeder core diameter is strongly related with the change of antenna performance, it is difficult to reach the goal to optimize them one by one, therefore, the optimization design function of HFSS should be adopted. Coaxial feed point to x-axis distance L1, coaxial feed point to y-axis distance W1 and coaxial feeder radius Rfeed are selected as the optimization design variables, the change range of L1 is set at 0mm-40mm, the change range of W1 is set at 0mm-45mm, the change range of Rfeed is set at 0.3mm-0.9mm, the optimization goal is $S_{11} < -20dB$ at 922.5MHz and 842.5MHz. The optimization results are: L1=16.0mm, W1=16.0mm, Rfeed=0.6mm.

7.3. Design results

After optimization, the parameters of label antenna are shown in Table 4.

Table 4 Design variables optimization value

Parameter Name	Variable Naming	Simulation Initial Value
Dielectric substrate thickness	H	2.7*mm*
Radiation patch length	L0	100.5*mm*
Radiation patch width	W0	111.0*mm*
Coaxial feeder radius	Rfeed	0.6*mm*
Distance from coaxial feed point to x-axis	L1	16.0*mm*
Distance from *coaxial feed point to y-axis*	W1	16.0*mm*

8. Analysis on the Performance of Label Antenna

8.1. Analysis on the anti-interference performance of label antenna

HFSS 13.0 software is adopted for modeling, operating the simulation analysis, the return loss curve of label antenna is shown in Fig. 8.

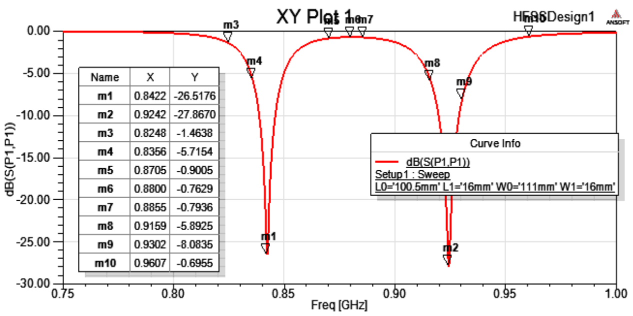

Fig. 8: S_{11} Analysis Results (L=100.5*mm*, W=111.0*mm*, L1=16.0*mm*, W1=16.0*mm*, Rfeed=0.6*mm*)

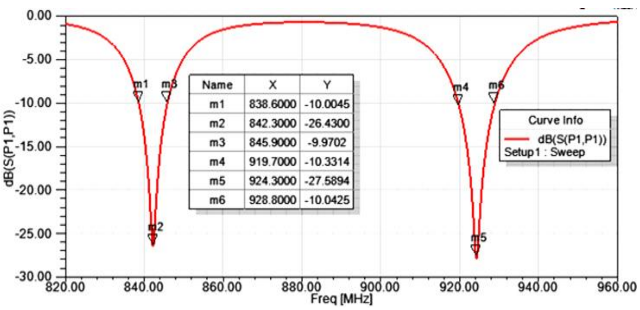

Fig. 9: Frequency Range Covered by $S_{11} \le -10dB$

It is known from Diagram 8, the return loss S_{11} value of different channels of mobile communication are shown in Table 5, which are over -10dB.

Table 5 Mobile communication channel S_{11} value

Channel	**S_{11} Value**
825-835MHz	-5.72< $\mathbf{S_{11}}$<-1.46
870-880MHz	-0.90< $\mathbf{S_{11}}$<-0.76
885-915MHz	-5.89< $\mathbf{S_{11}}$<-0.79
930-960MHz	-8.08< $\mathbf{S_{11}}$<-0.70

See Fig. 9 for the frequency range of $S_{11} \le -10dB$, 840MHz-845MHz channel is 838.6MHz-845.9MHz, 920MHz-925MHz channel is 919.7MHz-928.8MHz, which covers all channels of Chinese UHF RFID.

Please see Fig. 10 for the voltage standing-wave ratio VSWR of label antenna, see Table 6 for the VSWR ranges of different channels, the VSWR values of RFID channel are less than 2, the VSWR values of mobile communication channel are over 2.

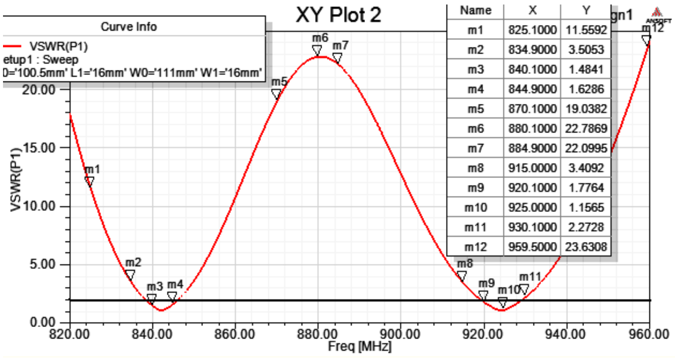

Fig. 10: voltage standing-wave ratio VSWR analysis result

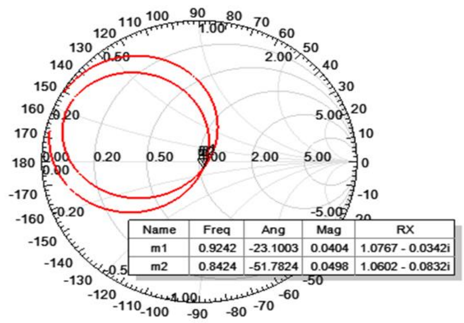

Fig. 11: Smith Circle Diagram Results of S11

Table 6. VSWR Value Range of Different Channel

Channel	**VSWR Value**
825-835MHz	3.51<VSWR<11.56
840-845MHz	1.48<VSWR<1.63
870-880MHz	19.04<VSWR<22.79
885-915MHz	3.41<VSWR<22.10
920-925MHz	1.16<VSWR<1.78
930-960MHz	2.27<VSWR<23.63

8.2. Analysis on the Gain of Label Antenna

1. See Fig. 11 for the Smith circle diagram results and input impedance, the normalized impedance at 924.2MHz is 1.0767-j0.0342, which means that the input impedance of the antenna at 924.2MHz frequency point is (53.835-j1.71) Ω, about 50Ω; the normalized impedance at 842.4MHz is 1.0602-j0.0832, which means that the input impedance of the antenna at 842.4MHz frequency point is (53.01-j4.16) Ω, about 50Ω.

2. See Fig. 12 for the 3D gain directional diagram, it is shown from the Diagram that the maximum radiation direction of the antenna is the normal direction of the microstrip patch, maximum gain is 7.28DB.

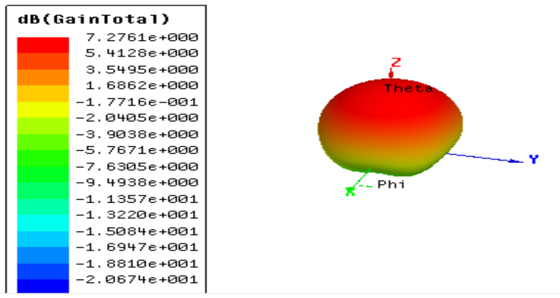

Fig. 12: 3D Gain Directional Diagram

8.3. Calculation of the maximum theoretical reading distance value of label [19]

On the assumption that label antenna and reader are matched perfectly and are on the same plane, the polarization loss of the label $\theta_{polarization}$ =1.0, antenna loss $\theta_{antenna}$ is 0.7, the power of the reader $P_{bsEIRP} = 4W$, the loss of the reader $\theta_{loadmatching}$ is 0.8; the minimum reading power of the chip P1 is $35\mu W$, the maximum theoretical reading distance of label is:

$$r_{\max} = \sqrt{\frac{P_{bsEIRP} G_{ant} \lambda^2}{(4\pi)^2 P_1} \theta_{loadmatching} \theta_{polarization} \theta_{antenna}} = 17.66(\mathrm{m})$$

9. Conclusion

The label antenna designed in this thesis features the working properties of metal resistance, mobile communication terminal interference resistance, high gain and dual-frequency, adapts the requirements of IT device assets management environment, and meets the GB/T 29768-2013 standard. In accordance with the principle of RFID label interference from the mobile communication channel, the dielectric substrate thickness h calculation formula is derived, which is adopted as the reference for selecting the dielectric substrate, and designing the label antenna of excellent performance and strong performance in resisting mobile communication terminal interference. During the design process, since the suitable antenna design parameters are selected, high antenna gain is obtained, S_{11} value is small, and the input impedance matching is excellent, which has reached the design indices requirements with good performance. After HFSS simulation verification, the mobile communication terminal interference resistant design method put forward in this thesis is correct and effective. The antenna design adopts simple structure, and is very easy for mass production with good prospect in engineering application.

The next work is to fabricate the physical sample of the antenna, and verify the effectiveness of this design in actual applications.

10. References

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