

A high gain RFID tag antenna design method of eliminating the interference of mobile communication terminal

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Abstract. China's UHF RFID band of 840 ~ 845MHz and 920 ~ 925MHz, distance of mobile communication CDMA800, GSM band near, vulnerable to interference in mobile communication system, resulting in demodulation bit error rate increased RFID tags. The interference of mobile communication system formation mechanism analysis, this paper puts forward a design method of UHF mobile communication terminal RFID tag antenna anti interference, deduced the calculation formula of the thickness H of dielectric substrate, and then use HFSS repeated experiments, to determine the dielectric substrate reasonable relative dielectric constant ϵ_r value, loss tangent $\tan \delta$ value, which can design a high gain RFID tag antenna anti interference of mobile communication frequency band. The simulation results show that the, the RFID band return loss values S11 were less than -10dB, the CDMA800 and GSM band return loss values S11 were greater than -10dB, the RFID band Voltage VSWR values were less than 2, the the CDMA800 and GSM band Voltage VSWR values were greater than 2. The RFID tag antenna maximum gain of 7.28dBi, the maximum read distance theory valuation 17.66m.

Introduction

UHF RFID tag without external power supply, and has the characteristics of read-write distance can be up to above 10m, the data communication at rates up to 640K, one-time can read thousands of tags, the manufacturing cost is low [1]. In 2013 November, the first RFID in China (tag) the national standard "information technology of radio frequency identification of 800/900MHz air interface protocol" (GB/T 29768-2013) release, UHF RFID technology has become the mainstream technology in the field of RFID in China. But in the application of RFID system in the process, there are still low reading rate, read range is small, easy to be disturbed, resulting in the promotion and popularization of difficulties. Has been building good System fault more also, seriously affecting the normal use. The interference of mobile communication system is a problem need to be solved in the application.

China UHF RFID band for the 840-845MHz and 920-925MHz, near CDMA800(down870~880MHz, upstream825~835MH) and GSM(down930~960MHz, upstream885~915MHz),in the UHF RFID label work, vulnerable to interference in mobile communication system, resulting in RFID tags demodulation bit error rate increased. The source of interference is mainly the mobile communication terminal equipment in the workplace [2]. In this paper, a detailed analysis of the formation mechanism of interference, this paper puts forward a design method of UHF RFID tag antenna anti interference of mobile communication terminal.

In the RFID tab design process, use of HFSS repeated experiment, to determine the dielectric substrate reasonable relative dielectric constant ϵ_r and Loss tangent $\tan \delta$ value, antenna maximum gain reaches 7.28dBi, the maximum read distance theory valuation 17.66m.

Analysis of the formation process of mobile communication terminal interference

The equivalent circuit model of label

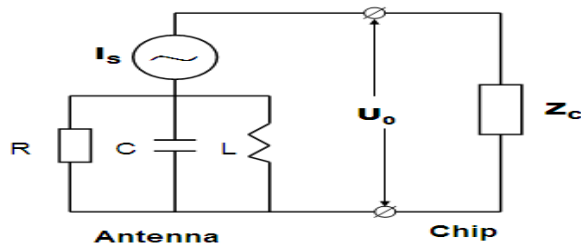


Fig. 1 Equivalent circuit label model

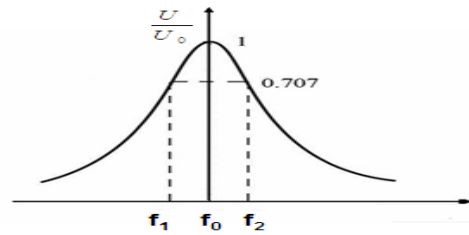


Figure 2 Distribution of the pass band of the antenna circuit

Microstrip antenna is equivalent to a parallel circuit[3], as shown in Figure 1, reader inquiry signal induces a current I_s on the antenna input impedance, Z_c chip. The antenna circuit admittance:

$$Y = G + j(\omega C - 1/\omega L) \quad (1)$$

The role of U in the end voltage of the chip impedance:

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

When that happens, parallel resonance, resonant frequency:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (3)$$

At this time U maximum value U_0 . The antenna circuit passband distribution shown in Figure 2, the antenna circuit bandwidth:

$$BW = f_2 - f_1 \quad (4)$$

Said frequency selective antenna, i.e. the signal in this frequency range will likely activate chip, the provisions of China's UHF RFID in the 806MHz ~960MHz to the antenna port launch complex shot limit requirements for -52dBm.

Frequency band mobile communication and RFID China UHF frequency band

Table 1 of China's UHF mobile communication and RFID frequency band

CDMA800 Upstream	RFID	CDMA800 Down	GSM Upstream	RFID	GSM Down
825~835MHz	840~845MHz	870~880MHz	885~915MHz	920~925MHz	930~960MHz

Interference of mobile communication terminal for RFID Tags

It is seen from table 1, the CDMA800 uplink frequency band and RFID frequency band 840 ~ 845MHz, GSM uplink and downlink frequency band and RFID frequency band 920 ~ 925MHz away from the 5MHz, it is easy to produce intermodulation interference and intermodulation interference [4], if the UHF RFID tag antenna frequency selection performance is not ideal, the resonant bandwidth frequency of electromagnetic wave transmitting in mobile communication terminal tag antenna, also be the tag antenna induction and activation of the chip, the mobile communication terminal transmitting electromagnetic wave is coupled to the tag chip, since the information carried by electromagnetic wave is random, coding and signal of UHF RFID system is not the same, leading to tag chip input signal to noise ratio is reduced, RFID Tags Demodulation bit error rate increased [2].

Design method of anti interference of mobile communication terminal

For convenience of analysis, the table 1 of China's UHF RFID band and UHF band mobile communication range, drawing into UHF frequency classification map, see figure 3.

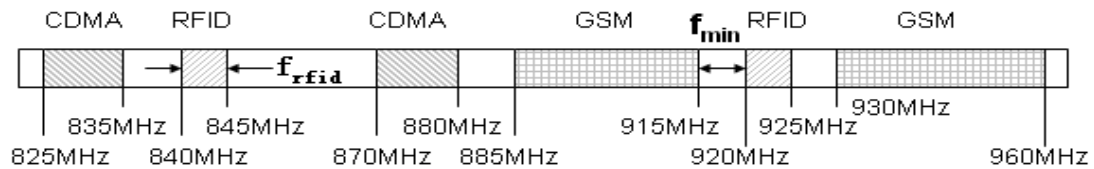


Figure 3 UHF band classification map of China

A RFID band width of f_{rfida} , CDMA, GSM, UHF band from recent distance for RFID band. From Figure 4 we can see, to eliminate the influence of mobile communication frequency band work for the label, the pass band can't antenna covers band part of mobile communication, so the maximum bandwidth of the antenna is:

$$BW = f_{rfida} + 2f_{\min} \quad (5)$$

Because

$$BW = \frac{(VSWR - 1)}{Q_T \sqrt{VSWR}} \quad (6)$$

The quality factor of the total antenna can be expressed as:

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

Among them, Q_r, Q_d, Q_c , the radiation, respectively, dielectric and conductor loss Q value. Due to practical and much larger than the approximate formula, the [5] given:

$$Q_T \cong Q_r = \frac{c\sqrt{\epsilon_{re}}}{4f_r h} \quad (7)$$

C is the speed of light, the effective dielectric constant, the resonant frequency, the thickness of the substrate medium. By (5) to (7) can be obtained:

$$h = \frac{c(f_{rfida} + 2f_{\min})\sqrt{\epsilon_{re}}\sqrt{VSWR}}{4f_r (VSWR - 1)} \quad (8)$$

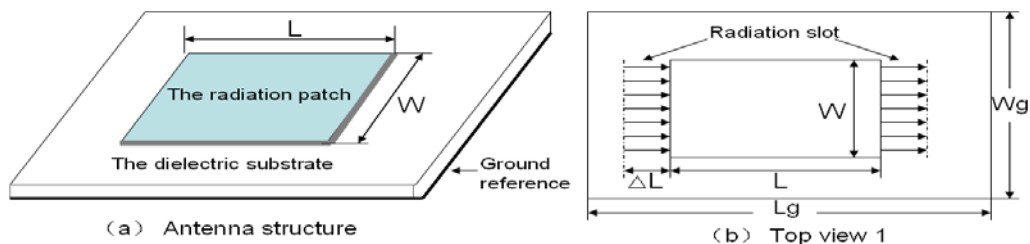
Reasonable selection of value, loss tangent value, according to (8) type calculation, completed the selection medium substrate material, RFID tag antenna bandwidth not covering CDMA, GSM band, the return loss is a mobile communication system in electromagnetic wave emission antenna, not to trigger chip, antenna has the property of resistance to mobile communication terminal interference good.

Design of a high gain UHF RFID tag antenna

The tag antenna model structure selection

This design uses the coax fed microstrip patch antenna structure as prototype design.

The basic structure of tag antenna consists of three parts: the radiation patch, a medium substrate, coaxial cable, as shown in figure 4.



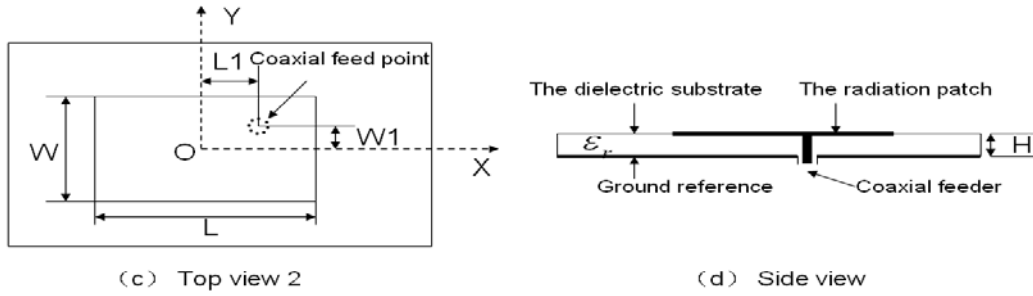


Figure 4 tag antenna structure

The tag antenna design index

RFID tag antenna is designed in this paper to follow the "information technology RFID Air Interface Protocol" (GB/T 29768-2013) standard, the design indices:

- 1) The work center frequency of 842.5MHz and 922.5MHz.
- 2) Anti interference performance of tag antenna system: the reflection coefficient $S_{11} \leq -20dB (VSWR \leq 2.0)$, reflection coefficient of different system $S_{11} \geq -10dB (VSWR \leq 2.0)$.
- 3) Maximum gain $G_{ant} \geq 6dB$.
- 4) The theoretical maximum distance $r_{max} \geq 10m$.

The calculation of radiation patch parameters

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

Sur ϵ_r, e, h, W , can calculate the effective dielectric constant ϵ_{re} .

$$\epsilon_{re} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{W} \right)^{-1/2} \quad (10)$$

$$\text{Medium wavelength } \lambda_g = \frac{c}{fr \sqrt{\epsilon_{re}}} \quad (11)$$

The radiation patch length L in theory $\lambda_g / 2$, because of the influence of edge field, in the design of the size of the L from the $\lambda_g / 2$ minus $2\Delta L$, so:

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

$$L = \frac{c}{2f_r \sqrt{\epsilon_{re}}} - 2\Delta L = 0.5\lambda_g - 2\Delta L \quad (13)$$

Substrate size determination

Distribution of substrate size on the radiation field has no obvious influence, from the view of reducing weight, the antenna installation area and reduce the cost, L_g, W_g should be as small as possible.

$$\text{Medium plate length } L_g = L + 0.2\lambda_g \quad (14)$$

$$\text{Medium plate width } W_g = W + 0.2\lambda_g \quad (15)$$

A coaxial feeder position parameters calculation

This paper adopts orthogonal method to realize dual band multimode.

For rectangular microstrip radiating patch, the feed point is positioned at the X axis, can stimulate the TM_{10} mode, this time as the center line of the feed point is positioned at the radiation patch Y direction, will not stimulate the $TM_{0n} (n = 1, 3, 5, \dots)$ mode. Similarly, when the feed point is located in the Y axis, can stimulate the TM_{01} mode, $TM_{m0} (m = 1, 3, 5, \dots)$ mode is not excited. If the feed point is placed in the patch near the diagonal position (see Figure 1 (c)), then this can stimulate

TM_{01} mode and TM_{10} mode, and can obtain the input impedance of the 50Ω , has realized the antenna with dual frequency work.

Feed position calculation formula is as follows [6]:

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

In the formula $\xi_{re}(L) = (\epsilon_r + 1)/2 + ((\epsilon_r - 1)/2)(1 + 12h/L)^{-1/2}$

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

In the formula $\xi_{re}(W) = (\epsilon_r + 1)/2 + ((\epsilon_r - 1)/2)(1 + 12h/W)^{-1/2}$

Simulation and optimization of tag antenna

Modeling of initial value

In order to reduce the influence of the mobile communication terminal, as far as possible from the resonant frequency of CDMA, the GSM band is farther. In the design, the definition of resonant frequency values a big first resonant frequency, the resonant frequency of small value a second resonant frequency, can be seen from Figure 4, the first resonant frequency of the antenna resonant frequency of desirable desirable 922.5MHz, second 842.5MHz, the initial parameter calculation of reference when the resonant frequency of the $f_r = 922.5\text{MHz}$, $f_{rid} = 5\text{MHz}$, $f_{min} = 5\text{MHz}$. Considering the applications without special restrictions installation weight area or volume of the antenna, but for the antenna gain higher, so take $\epsilon_r = 2.45$, PTFE base materials $\tan \delta = 0.0018$. The coaxial feed line radius 0.6mm. Take the data into the formula (5) to (17), get the initial design parameters of the antenna are shown in table 2.

Table 2 design variable definition and Simulation of initial value

The parameter name	The variable name	The simulation of initial value
The thickness of the substrate medium	H	2.7mm
Dielectric substrate length	Lg	142.8mm
Width of substrate	Wg	165.4mm
The radiation patch length	L0	101.1mm
The radiation patch width	W0	123.8mm
The radius of the coaxial feed line	Rfeed	0.6mm
The coaxial feed points to the X axis distance	L1	17.2mm
The coaxial feed points to the Y axis distance	W1	21.7mm
1/4 operation wavelength	Length	81mm
The radiation boundary length	AirBox_L	L0+2×Length
The radiation boundary width	AirBox_W	W0+2×Length
Radiation boundary height	AirBox_H	20mm+H+Length

Calculation and optimization of performance parameters

According to the antenna structure parameters obtained, using HFSS modeling and parameter calculation. See the return loss curve of the antenna is shown in Figure 5, the first resonant frequency values for the 916.1MHz, second resonant frequency is 758MHz, we can see that the first resonant frequency value and design index value of the smaller the gap, the second resonant frequency from the design of index value of the larger gap.

According to the previous theoretical analysis, the resonance frequency mode (i.e. first resonant frequency) is mainly determined by the radiation patch in the axial direction length L0, the resonant frequency of TM_{10} mode (i.e. second resonant frequency) is mainly decided by the radiation patch in the direction of X axis length W0. Show according to (13) type L0 value calculated accurately; (9) type according to the calculated W0 value is big, from the previous analysis, the calculation formula (9) is the maximum value of W0, the application can reduce (according to the repeated experiments, some can be reduced about 10%).

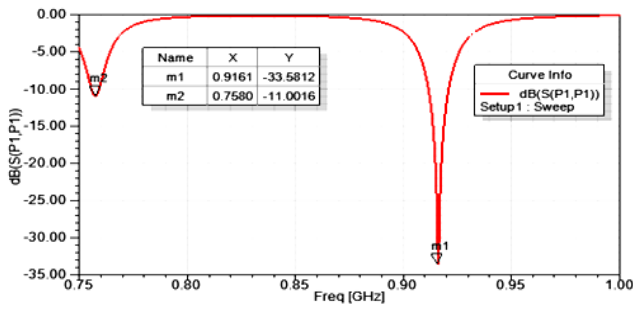


Figure 5 S11 analysis results
(L0=101.1mm, W0=123.8mm)

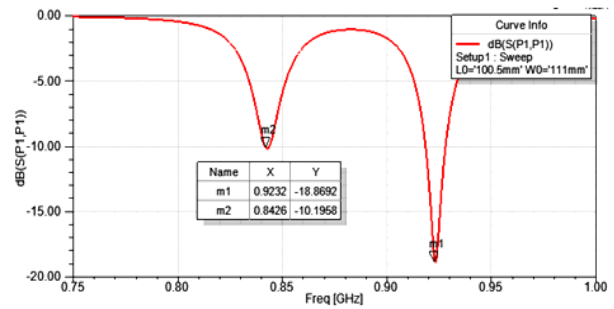


Figure 6 S11 analysis results
(L0=100.5mm, W0=111.0mm)

Parameter sweep analysis using HFSS function, respectively adding radiation patch length variable L0 and width of W0 for parameter calculation of scanning, and analyzes the relationship between the antenna resonant frequency and L0, W0. Seen from Figure 6, the L0=101.1mm first resonance frequency in the vicinity of the 922.5MHz but less than 922.5MHz, so the range of L0 value is 100mm ~ 101.1mm, step 0.1mm scan analysis, get the L0=100.5mm, a 923.2MHz value from the 922.5MHz closest to the. In the scan analysis of W0, according to experience, the first W0 value decreased 10%, namely W0 111.4 as the center, numerical plus or minus 5% about, namely scanning analysis range 105mm ~ 118mm, step 2mm, analysis, narrowing the range, and then analyzes the second scans, the step length of 0.1mm. Finally, as when W0=111.0mm, get a 842.6MHz value from the 842.5MHz closest to, see Figure 6.

As you can see from Figure 4, after adjustment of L0, W0 values, the resonant frequency achieves the goal of design requirements, but the resonance frequency 923.2MHz of the S11 value is -18.87, the resonant frequency of 842.6MHz, the S11 value is -10.20, not reaching the target requirements.

Adjust the feed position and feed wire core diameter can improve the performance of the antenna [7]. Because of the strong linkage changes feed position and feed wire core diameter on the performance of the antenna, a successively optimization is very difficult to achieve the goal, so need to use the function of HFSS optimal design. The choice of the coaxial feed to the X axis distance L1, the coaxial feed points to the Y axis distance W1, coaxial feeder radius Rfeed as optimization design variables, the variation range of L1 is set to 0mm ~ 40mm, the change range of W1 is set to 0mm ~ 45mm, the change range of Rfeed is set to 0.3mm ~ 0.9mm, the optimization goal is set to $S_{11} < -20dB$ in 922.5MHz, 842.5MHz. The optimization results: L1=16.0mm, W1=16.0mm, Rfeed=0.6mm.

The design results

After optimization, the parameters of the tag antenna is shown in table 3.

Table 3 the value of design variables optimization

The parameter name	The variable name	The simulation of initial value
The thickness of the substrate medium	H	2.7mm
The radiation patch length	L0	100.5mm
The radiation patch width	W0	111.0mm
The radius of the coaxial feed line	Rfeed	0.6mm
The coaxial feed points to the X axis distance	L1	16.0mm
The coaxial feed points to the Y axis distance	W1	16.0mm

Performance analysis of tag antenna

Anti jamming performance analysis of tag antenna

The use of HFSS 13 software operation modeling, simulation analysis, tag antenna return loss curve shown in figure 7.

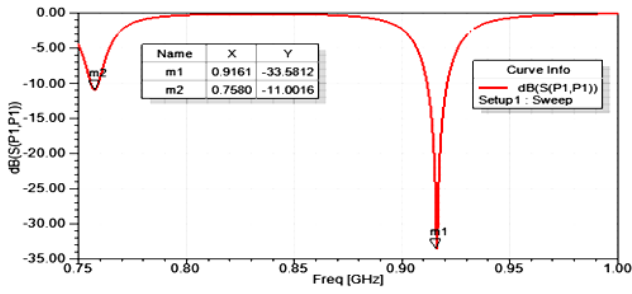


Figure 7 S11 analysis results

(L=100.5mm, W=111.0mm, L1=16.0mm, W1=16.0mm, Rfeed=0.6mm)

From figure 7, the return loss of S11 mobile communication frequency band of the values shown in Table 4, are more than -10dB.

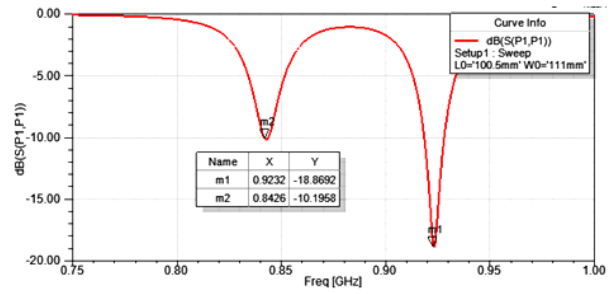


Figure 8 $S_{11} \leq -10dB$ frequency range covers

Table 4 mobile communication frequency band S11 value

Band	The value of S11
825~835MHz	$-5.72 < S_{11} < -1.46$
870~880MHz	$-0.90 < S_{11} < -0.76$
885~915MHz	$-5.89 < S_{11} < -0.79$
930~960MHz	$-8.08 < S_{11} < -0.70$

The frequency range of $S_{11} \leq -10dB$ see Figure 8 ,840MHz ~ 845MHz frequency band is 838.6MHz ~ 845.9MHz, 920MHz ~ 925MHz frequency range is 919.7MHz ~ 928.8MHz, covering all the band of UHF in China RFID.

Tag antenna voltage in Bobbi VSWR as shown in Figure 9, the frequency range of VSWR are shown in Table 5, the frequency of RFID VSWR value of less than 2, the mobile communication frequency band VSWR values are greater than 2.

Table 5 the frequency range of VSWR value

Band	The value of VSWR
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	$2.27 < VSWR < 23.63$

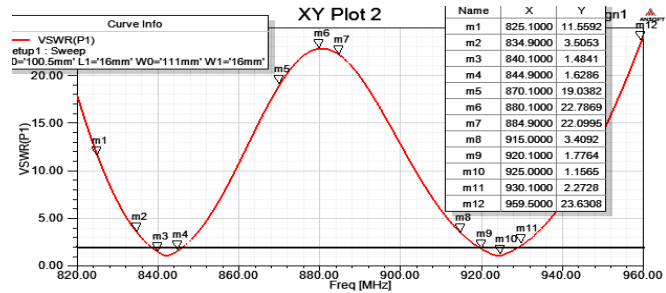


Fig. 9 voltage in Bobbi VSWR analysis results

Analysis of the tag antenna gain

1. The Smith results and input impedance circle diagram shown in Figure 10, the normalized impedance when 924.2MHz is $1.0767-j0.0342$, namely the antenna input impedance in 924.2MHz frequency point ($53.835-j1.71$) Ω , is about 50Ω ; normalized impedance 842.4MHz ($1.0602-j0.0832$) Ω , which is the input impedance of antenna in 842.4MHz frequency point for ($53.01-j4.16$) Ω , ca. 50Ω .

2. Three dimensional gain pattern shown in Figure 11, you can see the direction of maximum radiation from the antenna diagram is to the direction of microstrip patch, the maximum gain value 7.28dB.

3. The maximum read distance value theory to estimate the label[8]

Assuming the reader and the tag antenna perfect matching and in the same plane, the $\theta_{polarization} = 1.0$ tag antenna polarization loss, Antenna loss $\theta_{antenna} = 0.7$, the reader power $P_{bsEIRP} = 4W$,

reader loss of $\theta_{loadmatching}$ is 0.8; the chip needs minimal reading power $P_1 = 35\mu W$, label the maximum reading distance of theoretical estimates:

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

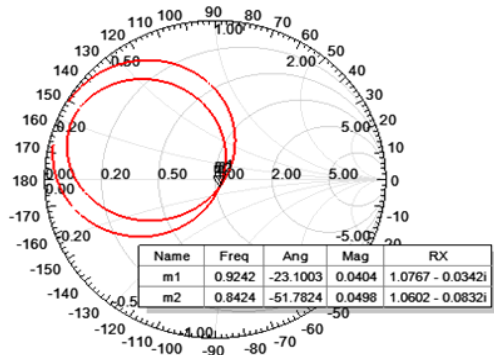


Figure 10 Results S11 Smith chart

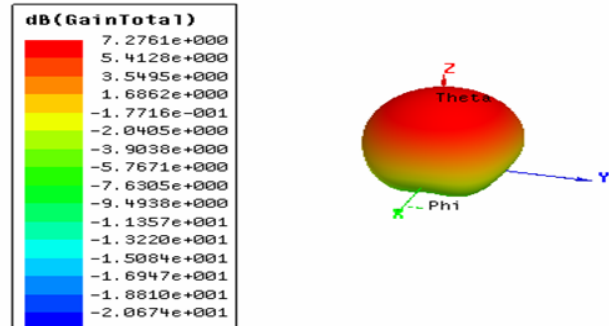


Figure 11 three-dimensional gain pattern

Conclusion

The simulation in the design of UHF RFID tag antenna in a mobile communication terminal authentication, anti interference design method proposed in this paper are correct, effective. Simulation results show that the calculated thickness, substrate medium according to the H formula, so to choose the medium substrate as the basis, can guarantee the tag antenna frequency selection performance is good, the ability of anti interference of mobile communication terminal. Because the parameters are chosen properly, the antenna gain is high, the S11 value is small, the input impedance is good, good to meet the design requirements. The design of the antenna structure is simple, easy batch production, and has good application prospect.

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