2021 International Conference on Computer, Network, Communication and Information Systems (CNCI 2021)

# *Design of Dual-band Antenna for RFID Reader*

**Yunyan Zhou**[1,a] **and Nianshun Zhao**[1,b]

*[1]Colleage of Mechanical and Electrical Engineering, Huangshan University,*
*Huangshan 245041, China*
*a. yanwork104@163.com, b. nszhao@hsu.edu.cn*
**Yunyan Zhou*

***Keywords:*** Dual-band, RFID reader, miniaturization, microstrip antenna.

***Abstract:*** A novel dual-band antenna of RFID reader is proposed. The antenna adopted a single layer substrate of FR4 medium. A four-pointed star was cut in the middle of the radiation patch, and a half four-pointed star was slotted on each side. Then the size reduction and dual-band coverage were realized. Through simulation and analysis, the geometric size of the antenna is 68mm×68mm×1.6mm, the operating band are 0.91GHz~0.935GHz and 2.40GHz~2.51MHz, and the relative impedance bandwidth are 2.72% and 4.49% respectively. Also, the antenna has good radiation characteristics in the operating band. The antenna can meet the requirements of the handheld RFID reader antenna with low cost and minimization.

## 1. Introduction

With the development of Internet of things (IOT) technology, the application of radio frequency identification technology (RFID) in our life is becoming more and more extensive. Compared with barcodes and QR codes, RFID electronic tags have the advantages of fast recognition speed, large information capacity and wide application environment. The information of RFID electronic tags needs to be obtained by RFID readers. The antenna of the RFID reader determines the reader performance and cost directly. RFID frequency bands mainly include UHF and microwave 2.45GHz band. However, the frequency bands of RFID in different countries and regions are different, such as the UHF band, it is 840MHz~845MHz and 920MHz~925MHz in China, 922~928MHz in Taiwan, and 917MHz~923.5MHz in South Korea etc.. And microwave 2.45GHz band coverage is generally 2.4GHz~2.483GHz. The traditional antenna of RFID reader works at a single band, which limits the use range of the reader. In order to make the RFID reader suitable for different wavebands, the broadband multi-band coverage of antenna has become a hot topic in recent years. On the other hand, the wavelength of UHF band is very long, which makes the size of the antenna very considerable, then limits the development of handheld RFID reader. Therefore, the miniaturization of the RFID reader antennas is also an urgent problem to be solved.

Currently, there are various technologies to realize multiband for antenna, such as, multi-layer technology [1-2], multi-branch [3-5], doubly-fed network [6], slot loading technology [7-12], fractal technology [12], etc., among which slot loading can not only realize antenna multi-band, but also realize broadband and miniaturization. Many scholars have done a series of research on the dual-band antenna of the RFID reader. For example, a dual aperture-stacked patch antenna for RFID reader antenna designed by Du Ting et al. works in two bands of UHF and 2.45GHz [8]. The antenna consists of a double-sided notches patch, a thick air layer and resonant aperture in the ground plane which makes the antenna profile too large. Nan Jingchang et al. extended the current path through a square slot cut in the middle of the radiation patch, and a four-sided slot and a four-corner cut of the radiation patch to achieve miniaturization and dual-band [9], which is suitable for UHF band and 2.45GHz band, however the 2.45GHz bandwidth is a little narrow. Wang Mingqi realized dual-band by loading two symmetrical C-type gaps in the patch, and realized tri-band through further design [10]. Niotaki K et al. used a half-wave dipole to cover 915MHz and 2.45GHz frequency bands in a 3D space of 60 mm×60 mm×60 mm [11].

In order to solve the problem of RFID reader antenna presently, an antenna was proposed to cover both UHF and microwave 2.45GHz bands, achieving the goals of smaller size and larger bandwidth, which makes application range of the RFID reader wider.

## 2. Antenna Descriptions

### 2.1.Antenna Structure

The configuration of proposed antenna is shown in Figure 1. The antenna substrate is made of a low cost glass fiber epoxy resin FR4 material, with dielectric constant of 4.4, loss tangent angle of 0.02, thickness of 1.6mm. The proposed antenna is fed by 50Ω coaxial. The current path of the antenna is changed by cutting the stars on the square patch, so as to achieve the purpose of reducing the size and achieving dual-band coverage. The impedance matching is realized by changing the position of the coaxial feeding point. The side length of the square ground is G, and the side length of the square radiation patch is L. In the middle of the radiation patch, a four-pointed star is dug out, and an half of the four-pointed star is slot in each of the four sides. The four-pointed stars are surrounded by four isosceles triangles. The bottom side length of the triangle is Sa, and Sb is the height of the triangle. In addition, a pair of isosceles right-angled triangles is cut on a pair of diagonal corners of the radiation patch, which is convenient for the adjustment and control of the high frequency band. The side length of the right-angled triangles is Tr.

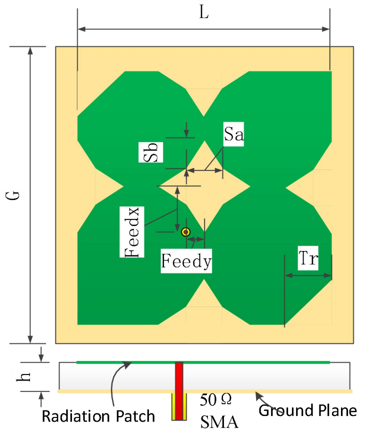


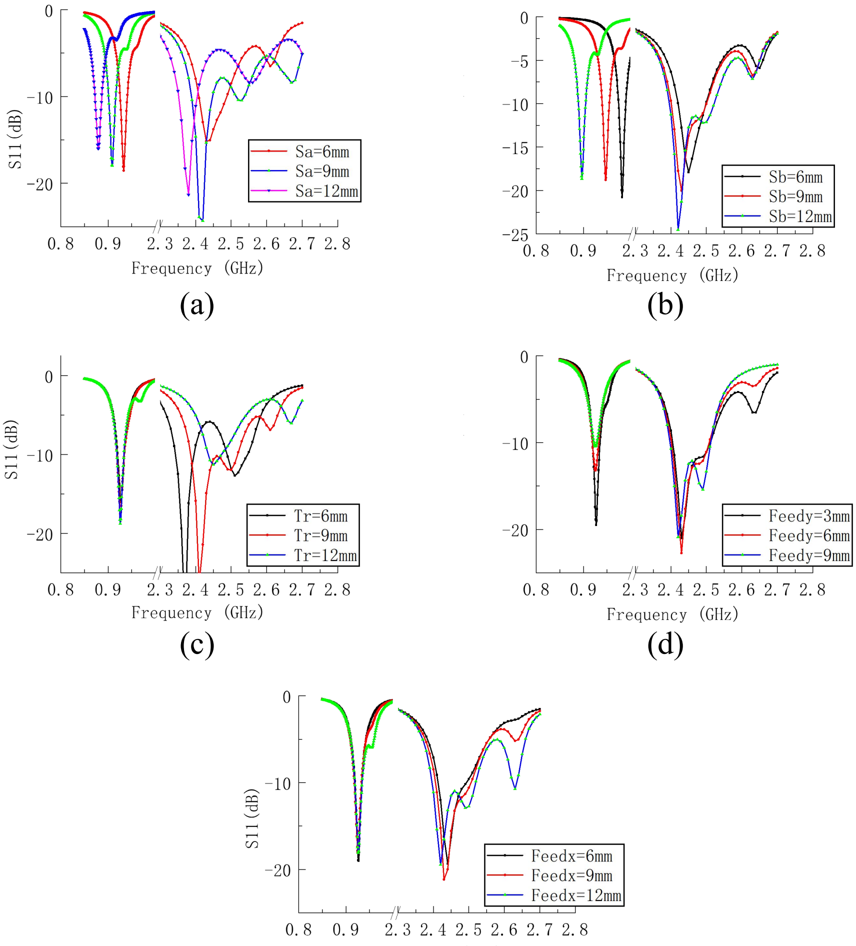
Figure 1: The geometry of the proposed antenna.

According to the principle of the microstrip antenna, the initial size of the patch can be preliminarily determined from Eqs. (1), where f is the resonance frequency, and ε_e is the corrected dielectric constant of the substrate. According to the formula, L = 70mm is preliminarily taken.

$$L \approx \frac{c}{2f\sqrt{\varepsilon_e}} \tag{1}$$

## 2.2.Principle of Operation

Figure 2 illustrates the effect of several key parameters to explain the principle of the antenna. Figure 2(a) shows that the larger the Sa, the lower the resonance point of both high frequency and low frequency. This is because the larger the slot star is, the more curved the current path is, and the longer the effective path is, thus reducing the resonant frequency. Therefore, the size of Sa can be coarsely adjusted to make the antenna work in the specified frequency band. When Sa takes 6mm, the low frequency resonance point is close to 920MHz, and the high frequency resonance point is around 2.45GHz.



(a) (b)

(c) (d)

(e)

Figure 2: Simulated S11 plot for different lengths of (a)Sa (b) Sb (c) Tr (d)Feedy (e)Feedx.

The effect of height Sb of the triangle in the four-pointed star shows in (b).When the Sb increases, the low-frequency resonance point decreases, but the difference of the high-frequency resonance point is small. Therefore, when the high-frequency resonance point is satisfied, the low-frequency resonance point can be satisfied by adjusting Sb. The figure shows that when Sb is between 9mm and 12mm, the low-frequency resonance point can be close to 920MHz.

As shown in Figure 2(c), it adjusts the length Tr which changes from 6mm to 12mm of triangle at the diagonal corner. The low-frequency resonance point does not change much, but the high-frequency resonance point increases as Tr increases. Therefore, the high frequency resonance point can be changed by controlling the size of Tr. When Tr is larger than 9mm, the high frequency resonance point is close to 2.45GHz.

In Figure 2(d), Feedy has little effect on the resonance frequency point, but with the change of Feedy, the return loss of low frequency resonance point changes continuously, while the return loss of high frequency resonance point does not change much. By decreasing Feedy, the return loss of the low-frequency resonance point increases. Considering that the four-pointed star is cut in the middle of the radiation patch, the Feedy is about 3mm.

It can be seen from Figure 2(e) that Feedx mainly affects the return loss of the high frequency resonance point, while it has little effect on the resonance frequency point and a relatively small effect on the return loss of the low frequency resonance point. The impedance matching of the high-frequency resonance point can be adjusted by controlling the size of Feedx.

## 3. Results and Discussion

Through further optimization and simulation debugging, the final geometric dimension of the antenna is determined as shown in Table 1. The antenna realizes the coverage of two frequency bands of RFID reader UHF and microwave 2.45GHz on a FR4 dielectric substrate of 68mm×68mm×1.6mm. Figure 3 shows the fabricated prototype of the proposed antenna.

Table 1: Dimensions for the proposed antenna.

| Parameters | G | h | L | Sa | Sb | Tr | Feedx | Feedy |
|---|---|---|---|---|---|---|---|---|
| Value/mm | 68 | 1.6 | 63 | 6.8 | 10.4 | 10 | 10 | 3 |

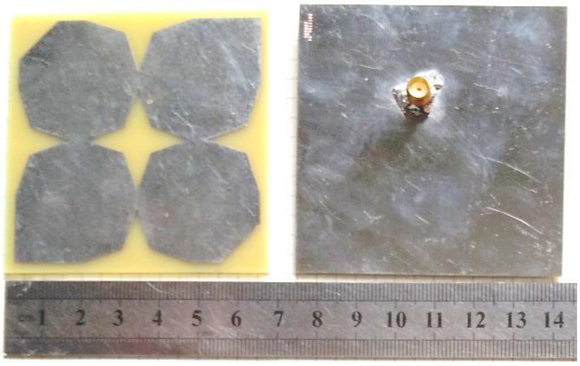


Figure 3: Prototype of the proposed antenna, top view and bottom view.

Figure 4 depicts the simulated and measured return loss S11 of the antenna. There is reasonably good agreement between the measured and the simulated results. The antenna exhibits S11⩽−10 dB bandwidth of 2.72% (0.925 and 0.91 ~ 0.935 GHz) at low-frequency band, and 4.49% (2.45 and 2.40 ~ 2.51 GHz) at high-frequency band. The antenna can meet the requirements of UHF band and microwave 2.45GHz band of RFID reader antenna.

The Smith chart of the antenna shows in Figure 5. The normalized impedances of the proposed antenna at 0.925GHz and 2.45GHz are 1.2696 + 0.1459i and 0.9415 + 0.3696i, respectively, which are relatively close to the center distance of Smith chart, indicating that the impedances match well at these two frequency points.

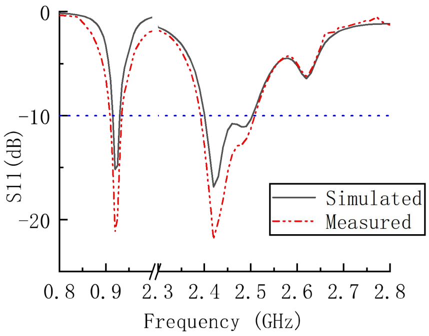


Figure 4: Simulated and measured S11.

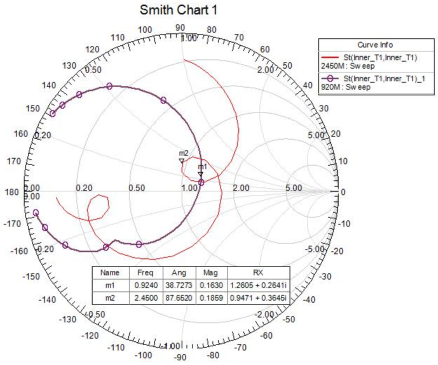
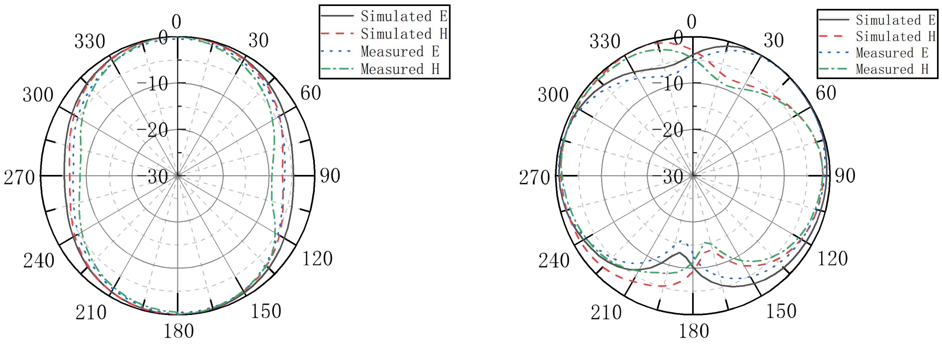


Figure 5: Smith chart of the proposed antenna.

Figure 6 is nominalized gain radiation patterns of the E and H planes of the antenna at 925MHz and 2.45GHz. The 925MHz radiation almost has omni-directional pattern while the 2.45GHz radiation has bidirectional (dumb bell shaped) pattern.



(a)

(b)

Figure 6: Measured and simulated radiation patterns at (a)925MHz (b)2.45GHz.

Several important parameters of the proposed antenna are compared with relevant references as shown in Table 2. Compared with the reference [2] [8], the proposed antenna is smaller in size and profile, but the bandwidth is a little narrow. Compared with the antenna designed in [9] [10], it has smaller profile and smaller size, also wider coverage.

Table 2: Comparison of the proposed antenna with existed literature.

| Ref | Size | Bandwidth（S11<-10dB） |
|---|---|---|
| [2] | 110mm×110mm×6.6mm | 0.911-0.933GHz，2.40-2.57GHz |
| [8] | 179.3mm×120mm×3mm | 0.870-0.940GHz，2.235-2.535GHz |
| [9] | 72mm×72mm×3mm | 0.910-0.938GHz，2.42-2.48GHz |
| [10] | 80mm×110mm×1.6mm | 0.895-0.935GHz，2.43-2.47GHz |
| Proposed | 68mmx68mmx1.6mm | 0.91-0.935GHz，2.40-2.51GHz |

## 4. Conclusion

A compact microstrip antenna with a four-pointed star cut in the middle and an half four-pointed star slotted on each side of the radiation patch was proposed. Satisfactory dual-band operation (914MHz ~ 935MHz and 2.40GHz ~ 2.51GHz) for RFID applications is achieved on a FR4 dielectric substrate of 68mm×68mm×1.6mm. The antenna adopts single-layer structure, without air layer, low profile, simple radiation patch structure. Hence, the antenna is easy to manufacture and has low price. The antenna may be a suitable candidate for the dual-band handheld RFID readers.

## Acknowledgments

This work is supported by the Natural Science Foundation of Anhui Provincial Department of Education under Grant KJHS2019B01 and KJHS2020B14.

## References

*[1] J. A. Ansari, A. Mishra, N. P. Yadava, et al. "Analysis of W-slot loaded patch antenna for dualband operation," AEU - International Journal of Electronics and Communications, Vol. 66, 32-38 (2011).*

*[2] Q. Liu, J. Y. Shen, J. G. Yin, et al. "Compact 0.92/2.45-GHz dual-band directional circularly polarized microstrip antenna for handheld RFID reader applications," IEEE Transactions on Antennas and Propagation, Vol. 65, 9, 3849-3854 (2015).*

*[3] A. Bekasiewicz, "Miniaturized dual-band branch-line coupler with enhanced bandwidth," Microwave & Optical Technology Letters, (2019).*

*[4] N. M. Sahar, M. T. Islam, N. Misran, "Design of dualband antenna for RFID applications," International Journal of Electrical and Computer Engineering, Vol.9, 4, 31-46 (2019).*

*[5] A. Pandey, R. Mishra, "Compact Dual Band Monopole Antenna for RFID and WLAN Applications," Materials Today Proceedings, Vol. 5, 1, 403-407 (2018).*

*[6] Q. Liu, J. Y. Shen, et al., "Compact 0. 92/2. 45GHz dualband directional circularly polarized microstrip antenna for handheld RFID reader applications," IEEE Transactions on Antennas and Propagation，Vol. 65, 9, 3849-3854 (2015).*

*[7] K. Niotaki, S. Kim, S. Jeong, et al., "A Compact Dual-Band Rectenna Using Slot-Loaded Dual Band Folded Dipole Antenna," IEEE Antennas and Wireless Propagation Letters, Vol. 12, 1634-1637 (2013).*

*[8] T. Du, X. P. Li, J. K. Liao, "Slot-loaded dual-band RFID reader antenna design," Journal of the Chinese Academy of Electronics Sciences, Vol.6,2,631-634 (2007).*

*[9] J. C. Nan, W. S. Wu, "Design of a new miniaturized dual-band RFID microstrip antenna," Electronic Components and Materials, Vol. 38, 7, 85-89 (2019).*

*[10] M. Q. Wang, "Research and Design of Multi-band Microstrip RFID Reader Antenna," Master's thesis, Guizhou University, 2015.*

*[11] D. Yan, A. S. Hu, J. Li, et al., "Design of T-shaped WLAN broadband dual-band antenna based on inverted L slot loading," Electronic Components and Materials,Vol.38,5,74-78 (2019).*

*[12] X. Ran, Z. Yu, T. Xie, et al., "A Novel Dual-Band Binary Branch Fractal Bionic Antenna for Mobile Terminals," International Journal of Antennas & Propagation, Vol.8,1-9 (2020).*