MINIATURIZATION OF MICROSTRIP PATCH ANTENNA BY USING TWO L-SHAPED SLOTS FOR UHF RFID READER

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Abstract. A novel design for miniaturization of microstrip patch antenna for the RFID reader is proposed. The proposed antenna design consists of two L-shaped slots on the patch and two parallel slots on the ground plane. The patch and the ground are shorted through a shorting probe. The area of the proposed antenna is reduced around 51% compared with the slot less one. The validity and feasibility of the proposed antenna has been simulated and analyzed by HFSS. The simulation results show that the proposed antenna has relatively good gain of 8.05dBi and radiation characteristics and it covers the required bandwidth, 902-928MHz. The measured results are compared with the simulated results, and good agreement is obtained.

Introduction

RFID technology is an automatic way to identify objects wirelessly through electromagnetic waves. Generally, RFID system consists of the tag, which saves information, and the reader, which reads the information saved in the tag. Recently, RFID technology has become a mainstream due to its various applications such as logistics, vehicles identification, automatic charge and industrial production, etc. [1-3]. A great demand of UHF RFID systems is expected to replace the current position of bar code systems [4].

However, the large-scale application of RFID technology is limited by the short identification distance of the reader, small recognition region, large antenna size and other technical imperfections. As an important part of the reader, antennas play a crucial role. The size reduction and gain enhancement of the UHF RFID reader antenna have been key issues of the system developer. Microstrip patch antennas are widely used due to such advantages as low profile, light weight, small size and ease of integration with other circuit components [5, 6]. To enhance the antenna gain, a large ground plane and a radiating patch have been used for antenna. But, a large size antenna cannot be applied to RFID systems.

In order to reduce the size of the antenna, many studies about miniaturization techniques of microstrip antenna have been done. In [7], miniaturization of a rectangular microstrip antenna using a magneto-dielectric substrate is discussed. The magneto-dielectric substrate used the metamaterial structure to reduce the antenna dimensions at 2.4GHz by increasing the constitutive parameters of the substrate. In [8], a method of folded structure is introduced to reduce the antenna volume with attaching for satellite communication terminal. An approach on miniaturization of microstrip patch antenna with loaded symmetrical strips in both non radiating side of the radiation patch is presented in [9]. In addition, miniaturization of the microstrip antenna is obtained in [10, 11] by cutting various shaped slot on the patch or the ground. This method reduced the size of antenna up to 86% in [10] and 67% in [11], respectively. Although the size of the antenna is reduced by the above methods, the performance of the antenna also degrades, such as the low gain and the narrow impedance bandwidth. There is a tradeoff between the size of the antenna and its performance. Therefore, different performance norms of the antenna should be chosen in different applications.

In this paper, a miniaturized microstrip patch antenna for the UHF RFID reader is proposed. The proposed antenna consists of two L-shaped slots on the patch and two parallel slots on the ground plane. The patch and the ground are shorted through a shorting probe. The probe connects to SMA.
connector, so the antenna can be driven by a standard 50Ω coaxial cable. The area of the antenna is reduced about 51% compared with the slot less one. The proposed antenna has a good gain and impedance bandwidth for UHF RFID systems.

**Antenna Design**

For the rectangular microstrip patch antenna, the following equations are used to calculate its width \(W\) and length \(L\),

\[
W = \frac{c}{2f} \left(\varepsilon_r + 1\right)^{1/2}
\]

and

\[
L = \frac{c}{2f \sqrt{\varepsilon_e}} = -2\Delta L
\]

where

\[
\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + \frac{12H}{W}\right)^{1/2}
\]

\[
\Delta L = 0.412H \left(\frac{\varepsilon_e + 0.3}{\varepsilon_e - 0.258}\right) \left(\frac{W}{H} + 0.264\right)
\]

where \(\varepsilon_e\) is the dielectric constant of the medium, \(f\) is the operating frequency, \(c\) is the free-space wave-propagation velocity, \(\varepsilon_e\) is the effective dielectric constant, \(H\) is the thickness of the substrate, \(\Delta L\) is the length of equivalent radiation slot.

Eq. 1 and Eq. 2 show that increasing permittivity of the material can reduce the size of the microstrip antenna, but it will easily induce strong surface-wave, leading to increase in the loss, reduction in the gain and bandwidth. Slots in the radiation patch cut off the original current path so that the effective current path increases, leading to reduction in the resonant frequency, and thereby the size of antenna. Slots in the ground plane guide current bent, which increases effectively the current path, hence also reducing the resonant frequency. Furthermore, a slot in the ground plane can also reduce the Q value of the antenna, thus increasing antenna bandwidth.

For coaxial feed microstrip antennas, it is easy to adjust the position of feeding point. Note that the feeding point is generally at the center point in the direction of width as shown in Fig. 1. Such a choice is because that the feeding point which deviated from the middle point will stimulate the mode of \(\text{Tm}_{in}\), thus increasing cross-polarization radiation of the antenna.

The proposed microstrip patch antenna consists of the radiation patch, the substrate, the ground plane and a coaxial feed line, as showed in Fig. 1. The radiation patch and the ground plane are made of copper, and an air substrate of thickness \(H\) between them. Four nylon columns are used to connect the patch and the ground plane. The length, width, and thickness of the radiation patch are \(L\), \(W\), and \(h\), respectively. Two L-shaped slots are cut on the radiation patch. The ground plane is wider than the patch by 0.1\(\lambda\) on both sides, and it is also longer than the patch by 0.2\(\lambda\) on the top and bottom, as shown in Fig. 1. Two parallel slots are cut on the ground plane. The coaxial feed line pierces through the ground plane and then connects to the patch. This coaxial line diameter is \(D\), and it connects to SMA connector by conical structure. The location of the feeding point is in the center of the patch.
Results and Discussion

Various parameters like return loss, impedance bandwidth, gain, and radiation pattern are illustrated in this section. All the parameters have shown acceptable results.

Simulated and measured return loss characteristics for the proposed antenna are shown in Fig. 2. From the results, it is clearly observed that the good impedance matching is obtained by adjusting dimensions of the antenna. The measured results shows the -10 dB input return loss bandwidth is 52MHZ (880-932MHz), meeting the requirement for UHF RFID frequency designation.

![Diagram of the antenna](image)

Figure 1. The front view and the side view of the antenna.

![Graph of return loss](image)

Figure 2. Simulated and measured return loss of the antenna.

Fig. 3 shows the effect of changing the air substrate thickness on return loss. Simulation result demonstrates that resonant frequencies shifts downward with increasing substrate thickness.

Fig. 4 and Fig. 5 show return loss for various lengths of slot1 and slot2 on patch, respectively. It is clear that resonant frequency changes with slot length. With increasing slot length, resonant frequency shifts downward because current distribution paths and electrical length increase.
Figure 3. Return loss of the antenna for different substrate thickness.

Figure 4. Return loss for various lengths of slot1.

Figure 5. Return loss for various lengths of slot2.
The measured radiation patterns in the E- and H-plane respectively for the proposed antenna at 915MHz is compared with simulated results in Fig. 6. The overall tendencies of the simulation and measurement agree well with each other. As can be seen in Fig. 6, the measured gain of the antenna is 8.05dBi, and the 3dB beam width is $60^\circ$, $86^\circ$ in the E- and H-plane respectively. This antenna can apply to RFID systems.

Conclusion

A miniaturized microstrip patch antenna for the UHF RFID reader is proposed. The proposed antenna consists of two L-shaped slots on the patch and two parallel slots on the ground plane. The area of the antenna is reduced about 51% compared with the slot less one. The measured results show that the proposed antenna has relatively good gain of 8.05dBi, and the 3dB beam width is $60^\circ$, $86^\circ$ in the E- and H-plane respectively.

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References


