Abstract

This paper presents a compact microstrip antenna that can be attached to a metallic object to form a passive radio frequency identification (RFID) tag operating in the UHF band. The proposed antenna was etched on an FR4 substrate with an overall size of 60 mm × 45 mm × 1.6 mm, and it consists of a matching network, two radiating patches, and a ground plane. Each patch was extended using a meandered strip and was shorted to the ground plane via four metalized via holes to form a planar inverted-F antenna (PIFA). When mounted on a 50 × 50 cm² copper plate, the proposed antenna provided a 10-dB impedance bandwidth of 37 MHz (901~938 MHz) and a power transmission coefficient (PTC) of 0.86 at a frequency of 915 MHz. Moreover, the maximum reading range of the prototype metallic RFID tag, measured using an UHF RFID reader system, reached about 6.2 m at 4-W EIRP radiation power.

1. Introduction

Radio frequency identification (RFID) is a technology that uses radio waves to identify or track objects, and it has become very popular in various applications such as retail, transportation, and distribution logistics. RFID is divided into four categories depending on the frequency band in which it is operated: low frequency (LF, 125 KHz), high frequency (HF, 13.56 MHz), ultrahigh frequency (UHF, 860~960 MHz, 902~928 in America), and microwave frequency (MW, 2.45 GHz, 5.8 GHz) [1]. Recently, UHF-band RFID systems are attracting a lot of attention because they are able to provide better features such as higher reading speed and greater reading range at a low cost as compared to RFID systems operating in...
other frequency bands. A typical RFID system consists of a reader, a tag, and an embedded computer system. The communication principle of UHF RFID systems is based on backscattering: the reader transmits a radio signal to the tag, which then responds by backscattering its identification data to the reader. The RFID tag, which is affixed to the objects to be identified, comprises an RFID microchip and an antenna, and the latter is known as a tag antenna. The tag antenna is one of the most important components of an RFID system because it determines the size of the tag and greatly influences the reading range of the RFID system. A tag antenna design should meet the following requirements: compact size, low cost, good matching with the microchip, and linear or dual polarization. Moreover, the tag antenna design and optimization depend on the practical application environment because the characteristics of the object to be identified greatly influence the RF performance of the tag antenna attached to it [1] [2].

In many RFID applications, the tag needs to be placed on a metallic object. In such a case, the performance of conventional design tag antennas could deteriorate seriously because of the variation in the antenna input impedance, radiation pattern, and resonant frequency. To overcome this problem, a number of solutions have been proposed, such as using a planar inverted-F antenna (PIFA) or a patch antenna in the RFID tag [3][4] or using an artificial magnetic conductor (AMC) to configure the platform tolerant tag [5].

In this paper, we present the design of a compact microstrip PIFA antenna for use in passive RFID tags that can be attached to metallic objects. With one T-matching network and two radiating patches extended using meandered strips, the proposed antenna is compact and achieves good impedance matching as well as desirable power transmission and radiation characteristics over the UHF RFID band of 902 to 928 MHz. The maximum reading range of the prototype metallic RFID tag, measured using an RFID reader system, can reach about 6.2 m at 4-W EIRP radiation power.

2. Antenna geometry

Fig. 1 shows the geometry of the proposed compact microstrip antenna. The antenna is designed for operating in the frequency band of 902–928 MHz and with the center frequency of 915 MHz. It is fabricated on a double-sided FR4 printed circuit board (PCB) having a length and width of 60 mm and 45 mm, respectively. The FR4 PCB has a dielectric constant \(\varepsilon_r\) of 4.4, dielectric loss tangent \(\tan\delta\) of 0.002, and thickness of 1.6 mm. The antenna’s configuration is shown with respect to y-axis, and it consists of one T-matching network, two radiating patches extended using meandered strips, and a ground plane. The two patches as well as the meandered strips and the T-matching network are etched on the top layer of the PCB substrate and the ground plane is etched on the bottom. Each patch is shorted to the ground plane via four metalized via holes to form a planar inverted-F antenna (PIFA). The via holes, which control the antenna impedance and resonant frequency, are located on the lower edge of the patch, and the relevant geometric parameters such as the space between adjacent via holes (\(S\)), the distance between the left via hole and the left edge of the patch (\(W_2\)), and the distance between the via holes and the lower edge of the patch (\(L_3\)) are designed and optimized to achieve good impedance characteristics. The meandered strips are used in our design to increase the effective electrical length of the patch and accordingly contribute to the reduction in the overall size of the antenna. Also, the specific input impedance of the proposed antenna can be tuned slightly by simply adjusting the total length of the meandered strip for exact conjugate matching with the microchip.

The RFID microchip employed in our design is ATA5990, which is manufactured by Atmel Corporation, and it has an input impedance of \(12 - j150\) (\(\Omega\)) at 915 MHz. It is placed across a gap of 4 mm with its two output pins (pin1 and pin8) affixed to the metal edge of the gap (point A and point B), respectively. The Ansoft HFSS software is used to calculate and optimize all the geometrical parameters of the proposed microstrip antenna. The dimensions (in mm) of the prototype antenna shown in Fig. 1 are \(L = 60, W = 45, L_1 = 10.5, L_2 = 2, L_3 = 17, L_4 = 5.8, L_5 = 3.4, W_1 = 10.5, W_2 = 20, W_3 = 6.8, W_M = 2.0, W_G = 4.0, W_R = 0.8, W_S = 1.0, \) and \(S = 2.0\).
3. Results and discussion

The antenna was prototyped and evaluated. By using an Agilent 8753ES network analyzer and a balun, the input impedances of the prototype antenna were measured both in the open air and by mounting on a 50 × 50 cm² copper plate. The return loss (RL, dB) and the power transmission coefficient (PTC) were used to describe the impedance matching and energy transport between the proposed tag antenna and the microchip, respectively, and they were calculated as [6] [7]

\[
RL(dB) = -20\log \left| \frac{Z_C - Z_A^*}{Z_C + Z_A^*} \right|, \quad PTC = \frac{4R_C R_A}{|Z_C + Z_A|^2}
\]

where \(Z_C = R_C + jX_C\) is the microchip impedance, \(Z_A = R_A + jX_A\) is the input impedance of the proposed antenna and \(Z_A^*\) is the conjugate of \(Z_A\). The calculated results are shown in Fig. 2. It is clear from Fig. 2 (a) that impedance matching for a 10-dB return loss was achieved for frequencies 900.5~932 MHz (in open air) and 901~938 MHz (mounted on the copper plate), which cover the UHF RFID operating frequency band of North America (902~928 MHz). Moreover, it can be observed from Fig. 2 (a) that the center frequency increased slightly when the antenna was mounted on the metal plate. Fig. 2 (b) shows that PTC was maximized, i.e., 0.76, at a frequency of 913 MHz in open air. However, this value increased to 0.78 when the antenna was mounted on the metal plate, and it reached a maximum of 0.86 at a frequency of 915 MHz.

Fig. 3 shows the simulated radiation patterns of the proposed antenna at 915 MHz. As expected, the maximum radiation is in the +z direction with a peak gain of 0.95 dBi in the open air and 1.9 dBi when it was mounted on the 50 × 50 cm² copper plate.

To evaluate the performance of the proposed RFID tag antenna, a UHF XCRF-860 RFID reader system was used to validate the reading range of the prototype tag, which comprised the proposed antenna and the ATA 5990 microchip. Table 1 shows the measurement results. The measurement was performed at a radiation power of 4 W (EIRP) and a minimum microchip power of 12 μW. It is clear that when the tag was mounted on the metal plate, the reading range increased, reaching a maximum value of 6.2 m.
Fig. 2 The calculated results (a) Return loss and (b) power transmission coefficient (PTC) between proposed antenna and ATA5990 microchip

Fig. 3 Simulated radiation patterns of proposed antenna, measured at 915 MHz
(a) in open air and (b) by mounting on 50 x 50 cm2 copper

Table 1. Measured reading range of prototype tag

| Frequency (MHz) | 912 | 913 | 914 | 915 | 916 | 917 | 918 |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| Range (in open air) | 4.8 m | 5.4 m | 5.2 m | 4.6 m | 4.0 m | 3.8 m | 3.0 m |
| Range (on metal plate) | 4.2 m | 5.2 m | 6.0 m | 6.2 m | 6.0 m | 5.7 m | 4.5 m |

4. Conclusions

This paper presents a compact microstrip planar inverted-F antenna (PIFA) for use as a tag antenna in passive RFID systems. Simulation and measurement results show that the proposed antenna achieves good performance in terms of impedance matching and power transmission between the antenna and the
ATA5990 RFID microchip over the UHF RFID frequency band of 902–928 MHz. Moreover, simulated radiation patterns of the proposed antenna mounted on the metal plate indicate an improved performance. The maximum reading range of the prototype metallic RFID tag, measured using an UHF RFID reader system, can reach about 6.2 m at 4-W EIRP radiation power.

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References

[1] R. Want. An introduction to RFID technology. *IEEE Pervasive Computing* 2006;5(1):25-33.
[2] X. Qing and Z. N. Chen. RFID Tag Antennas. Chapter 3 in Antenna for Portable devices, (Z. N. Chen Ed.). London:Wiley;2007, pp. 59–112.
[3] C.-H. Tsai, H.-D. Chen, Y.-H. Tsao, and C.-Y. Kuo. Low-profile PIFA array RFID tag antenna mountable on metallic objects. *IEEE Antenna and Propagation Society International Symposium* 2010, July 2010, Toronto, Canada.
[4] B. Yu, S. J. Kim, B. Jung, F. J. Harackiewicz, and B. Lee. RFID tag antenna using two-shorted microstrip patches mountable on metallic objects. *Microwave Opt. Technol. Lett.* 2007;49(2): 416-417.
[5] Y. C. Or, K. W. Leung, R. Mittra, and K. V. S. Rao. Platform tolerant RFID tag antenna. *IEEE Antenna and Propagation Society International Symposium* 2007, July 2007, Honolulu, Hawaii.
[6] G. Marrocco. The art of UHF RFID antenna design: Impedance- matching and size-reduction techniques. *IEEE Antennas and Propagation Magazine* 2008;50(1):66-79.
[7] K. V. Seshagiri Rao, P. V. Nikitin, and S. F. Lam. Antenna design for UHF RFID tags: A review and a practical application. *IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION* 2005;53(1):3870-3876.