Low-Profile Broadband RFID Tag antennas mountable on metallic objects

MingYin Lai*[1], RongLin Li[1], and M. M. Tentzeris[2]
[1]School of Electronic and Information Engineering
[1]South China University of Technology, Guangzhou 510640, China
[2]School of Electrical and Computer Engineering
[2]Georgia Institute of Technology, Atlanta, GA 30332-0250, USA
Email: lmyscut@yahoo.com.cn

I. Introduction

Radio Frequency Identification (RFID) systems in the UHF (Ultra High Frequency) have become more and more popular in different service industries. In many applications, the tag antenna needs to be placed on a metallic object. In this scenario the performance of most popular dipole-like antennas will be seriously decreased because of the variation of the antenna impedance. Many planar inverted-F antenna (PIFA) configurations used for metallic objects can be found in scientific papers [1]-[3], but the bandwidths achieved are narrow. In [4], Li Xu proposed a broadband RFID Tag antenna with two shorted patches, but its bandwidth became narrow as placed on a metal plate. On the other hand the antenna in [4] has a thickness of 4.6 mm, which is not suitable for some applications. In [5], L. Mo developed a broadband UHF RFID tag antenna by embedding a pair of U slots on the radiating patch to excite a new resonant mode, but at the price of lowered antenna efficiency, which leads to a shorter reading range. It has been reported that by using additional patches directly coupled or gap coupled to the radiating edges of a rectangular patch, a broadband antenna can be achieved [6]. In this paper, we will demonstrate that adding gap-coupled parasitic patches to the driven patch can excite additional resonant modes for RFID Tag antennas thus the bandwidth can be greatly enhanced.

II. Antenna Configuration

As showed in Fig.1, we developed two broadband antennas with one (a) or two (b) parasitic patches. The broadband antennas are fabricated on a 1.6 mm FR-4 substrate ($\varepsilon_r = 4.4$, $\delta = 0.02$) with a ground plane, a shorting plane, a driven patch and parasitic patches. The RFID microchip can be placed at a 3 mm width feed line and the conjugate match between antenna and microchip can be achieved by adjusting the length of the inset feed line L_i and the length of a short stub line L_s [4]. In our design, L_i =22 mm and L_s =6 mm. The parasitic patch of Antenna (A) (Fig.1a) has a length (L_2) that is slightly different from the length of driven patch (L_1), thus excites a novel resonant mode at the frequency nearby the fundamental resonant frequency of driven patch, making the bandwidth enhancement possible. It is found that the amplitudes of the two resonant modes can be adjusted by changing the width of the driven patch (W_1) and the width of the parasitic patch (W_2). It is found L_1=85 mm, L_2=84 mm, W_1=39 mm, W_2=17 mm and S=2 mm for an optimal design. Antenna (B) (Fig. 1b) with one more parasitic patch at the left side of the driven patch with length(L_2) slightly different from the driven patch and the right parasitic patch excites three different resonant modes; thus a further wider bandwidth can be achieved. The amplitudes of the three resonant modes can be tuned by varying the width of driven patch (W_1) and the widths of two parasitic patches (W_2, W_3). In the proposed Antenna (B), L_1=85.5 mm, L_2=84.5 mm, L_3=85 mm, W_1=34 mm, W_2=9 mm, W_3=27 mm, S_1=2 mm and S_2=1 mm. A prototype of Antenna (B) is pictured in Fig. 1c.

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III. Results and Discussion

The antennas are designed for RI-UHF-STRAP-08, which has an input impedance of 13.2-j61 ohm at 915MHz and a minimum activation power of -13dBm. The simulations are carried out using Ansoft HFSS software.

The simulated impedance characteristic is showed in Fig. 2. It is observed that Antenna (A) excites two resonant modes while Antenna (B) excites three. For Antenna A, the first resonant mode is excited by the driven patch with longer length, and the second resonant mode is excited by the parasitic patch. As for Antenna (B), the first resonant mode is excited by the driven patch with longest length while the second resonant mode is excited by the left-side parasitic patch with longer length and the third resonant mode is excited by the right-side parasitic patch. We use the power reflection coefficient $|s|^2$ to describe the energy transport between the tag antenna and the chip, which can be calculated by: $|s|^2 = \left|\frac{Z_c - Z_a^*}{Z_c + Z_a}\right|^2$, where Z_c and Z_a is the impedances of the microchip and antenna, respectively. The calculated results are shown in Fig. 3. The half-power bandwidth of Antenna (A) is 140 MHz in free space and 133 MHz when placed at the centre of a 400 mm × 400 mm metal plate. The half-power bandwidth of Antenna (B) is 153 MHz in air and 148 MHz on metal plate. The power reflection coefficient of Antenna (B) is lower than -7dB in the UHF RFID frequency bands (840-960 MHz). The simulated gains of our proposed antennas from 840 MHz to 940 MHz are depicted in Fig.4, It is observed that the gains as the antenna is mounted on metal plate are somewhat higher than those in air because of the reflection effect of the metal plate. By using Friss free-space transmission formula $d_{\max} = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP \times G_a \times (1-|s|^2)}{P_{th}}}$, where EIRP=4W, P_{th} = -13dBm, G_a is the gain of the antenna, λ is the wavelength, $|s|^2$ is power reflection coefficient, we can calculate the maximum reading-range. The result for reading-range is showed in Table 1.

IV. Conclusion

Two novel broadband UHF RFID tag antennas with one or two parasitic patches have been presented. The half-power bandwidths of proposed antennas are 140 MHz for one parasitic patch (Antenna A) and 153 MHz for two parasitic patches (Antenna B). When the antennas are mounted on a metal plate, the bandwidths become 133 MHz for Antenna (A) and 148 MHz for Antenna (B), which still cover the RFID UHF frequency range (840-960 MHz). In the future, the antenna measurement will be carried out.

Acknowledgment

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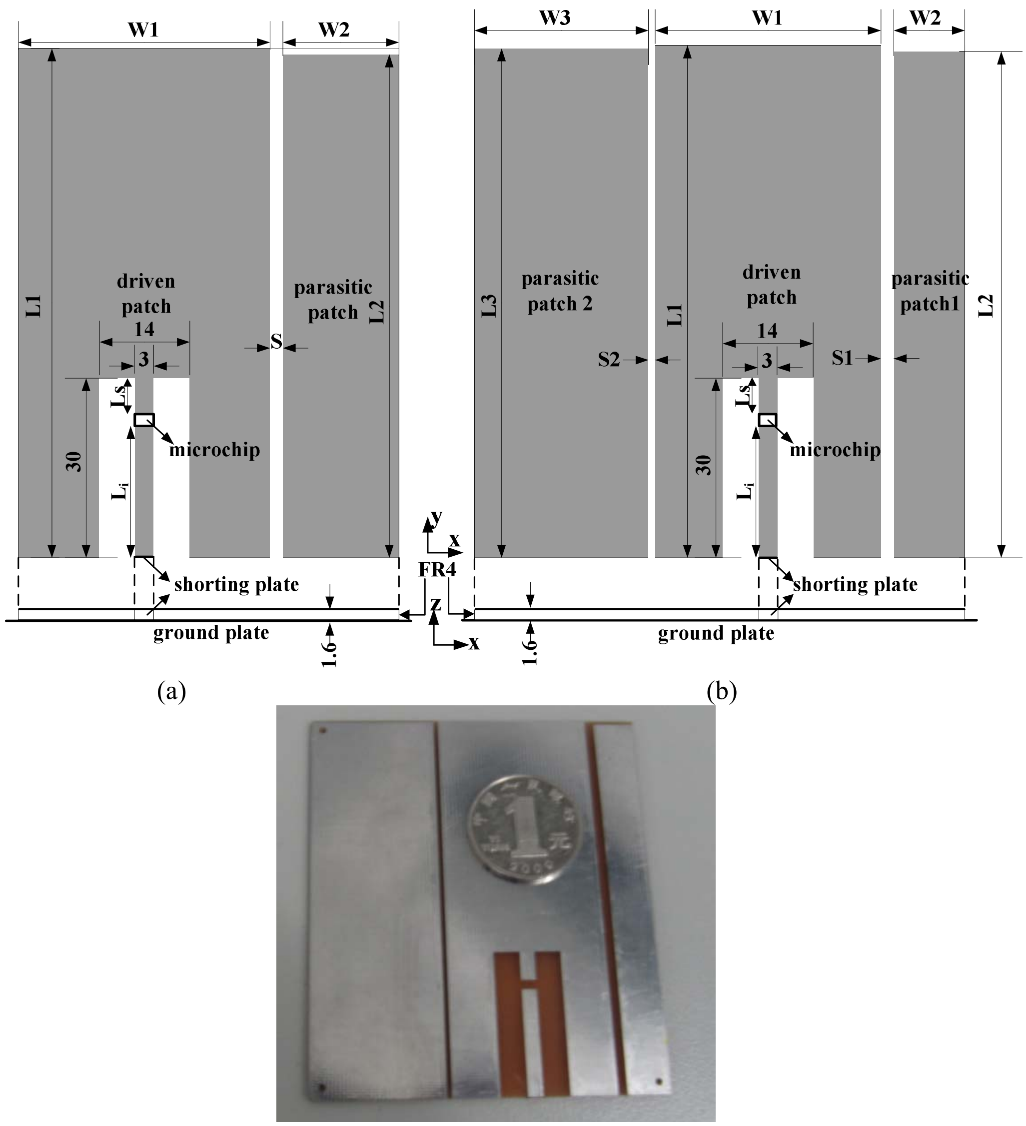
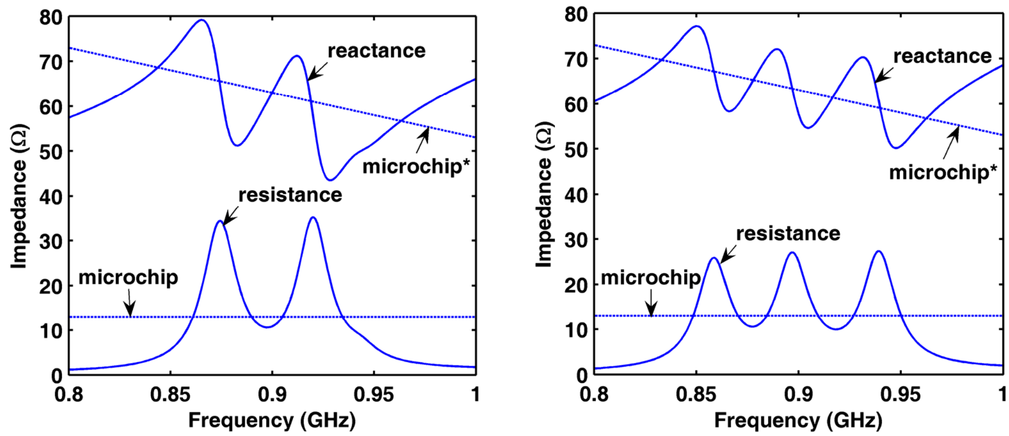


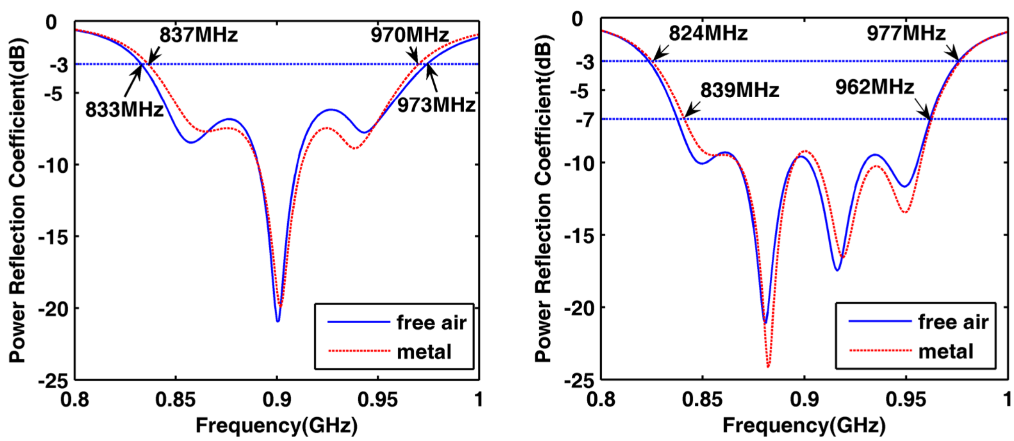
(c)

Fig. 1. Configuration of the proposed broadband antenna: (a) Antenna A with one parasitic patch, (b) Antenna B with two parasitic patches, (c) A photograph of Antenna B.



(a) (b)

Fig. 2. Simulated impedance characteristic of proposed antenna: (a) Antenna A, (b) Antenna B (* denotes conjugate value).



(a) (b)

Fig. 3. Calculated power reflection coefficient of the proposed antennas: (a) Antenna A, (b) Antenna B.

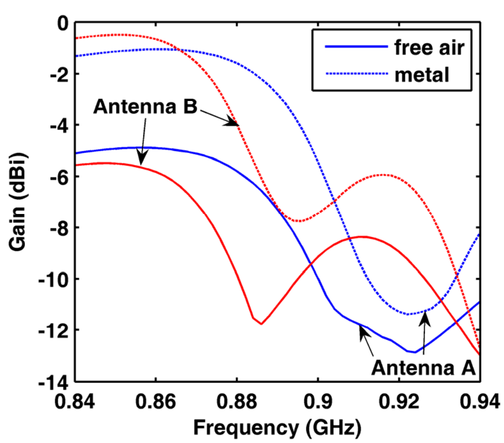


Fig. 4. Simulated gains of the proposed antennas

Table 1 Calculated Reading-Ranges

	867MHz in free space	867MHz on metal	915MHz in free space	915MHz on metal
Antenna A	4m	6.2m	2.3m	2.7m
Antenna B	3.7m	6.4m	2.9m	4m