Planar Broadband Tag Antenna Mounted on the Metallic Material for UHF RFID System

Jui-Han Lu, *Senior Member, IEEE*, and Gao-Ting Zheng

***Abstract*—A novel broadband design of planar tag antenna mounted on the metallic objects for the UHF radio frequency identification (RFID) system is proposed. We derive a new resonant mode that is excited with frequency shifting to enhance the operating bandwidth for broadband operation by employing the shorting pins posted at the corner of the proposed tag antenna. The obtained impedance bandwidth across the operating band can reach about 112 MHz (12.5%) for the UHF band, which is from 850 to 962 MHz. Also, with unidirectional pattern, the measured reading distance is about 5.2 m as the proposed tag antenna mounted on the metallic object.**

***Index Terms*—Broadband, radio freqnency identification (RFID), tag.**

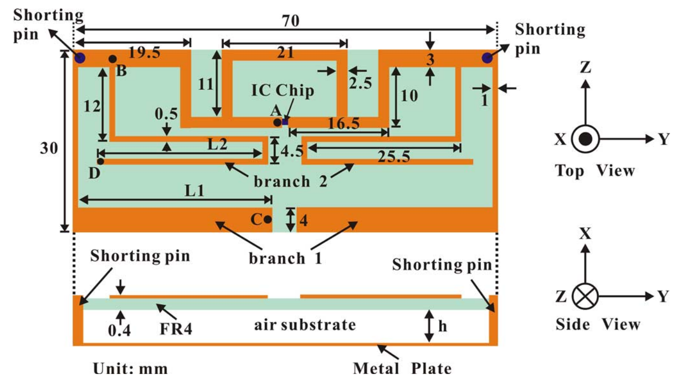

Fig. 1. Geometry of the proposed metal tag antenna with dual-branch strips with the shorting pins for broadband operation.

I. Introduction

RADIO frequency identification (RFID) technology provides wireless identification and tracking capability that is more convenient than the use of bar codes and optical scanners [1]. The numerous potential applications of the RFID system make ubiquitous identifications possible at frequency bands of 125 kHz (LF), 13.56 MHz (HF), 860–960 MHz (UHF), and 2450 MHz (microwave). Recently, the UHF RFID system has obtained more attraction in supply chain management and bioengineering because it can provide longer reading distance, fast reading speed, and large information storage capability. The tag antenna is the pivotal role for an RFID system to transmit/receive the modulated information for identification. The detection range and accuracy are directly dependent on the performance of reader/tag antennas. In many practical applications, RFID tags need to be mounted on the metallic objects. However, there are some problems that must be overcome for UHF label tags attached on the surface of metallic objects due to the electromagnetic wave scattering from the metal plane. Some metal tag antennas have been presented by using planar inverted-F antenna (PIFA) structures [1], [2], a dipole antenna [3], slits structure [4]–[7], a T-matching network [8], and a planar inverted-E antenna [9]. However, the above presented designs need larger dimensions of a tag antenna that is unable to meet the dimension consideration of the product. Moreover, the half-power matching bandwidth of the above tag designs [4], [6] cannot agree with the specification of the UHF band (860–960 MHz). In fact, the broadband tag antenna has increasingly become much needed in design as to meet the operating band specification of the UHF RFID system in any country and is necessary to overcome the operating frequency shift and impedance variations due to various materials or the manufacturing process errors.

In this letter, a novel broadband UHF tag antenna with unidirectional reading pattern is proposed to resolve this problem. By setting up dual-branch strips with the shorting pins posted at the corner of the proposed tag antenna, a new resonant mode is excited with frequency shifted closely to the fundamental mode to enhance the operating bandwidth of the tag antenna through properly adjusting the length of the branch strips. The measured half-power bandwidth of the proposed broadband tag antenna is 112 MHz (850–962 MHz), which includes the entire UHF RFID bandwidth. With its unidirectional reading pattern, the maximum reading distance is about 5.2 m as the tag antenna practically mounted on the metal material. Details of the proposed UHF RFID tag antenna design are described, and its experimental results from the obtained broadband performance as operating at 900 MHz band are presented and discussed as well.

II. Antenna Design

As shown in Fig. 1, dual-branch dipole strips (branches 1 and 2) are arranged with the shorting pins posted at the corner of this proposed tag antenna mounted above the back metal plate (a 0.2-mm-thick copper plate with the dimension of 70×30 mm^2 in this study) with the air substrate of the thickness h. The overall antenna size of 70×30 mm^2 is etched onto an inexpensive FR4 substrate with the substrate of thickness (0.4 mm) and relative permittivity $\varepsilon_r(4.7)$. An inverted U-shaped shorting

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The authors are with the Department of Electronic Communication Engineering, National Kaohsiung Marine University, Kaohsiung 811, Taiwan (e-mail: jhlu@webmail.nkmu.edu.tw).

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stub is introduced to connect with the arms of this proposed dipole tag antenna to form a closed loop. The impedance of the microchip (Higgs-2 used in this study [10]), which is connected between two feed points of the closed loop, is (17-j 120) Ω at the operating frequency of the 925-MHz band. The first branch strip (branch 1, from points A to C) with the total length of about 103.5 mm is settled around the edge of the proposed tag antenna to excite 880-MHz operating mode. By employing the shorting pins posted at the corner of the proposed tag antenna to connect with the back metal plate, the capacitive effect between the branch strip and the back metal plate decreases to make the operating frequency shift higher—just as the compact operation of the microstrip antenna with a shorting pin [11]. Compared to the operating wavelength of the 880-MHz band, the total length of the branch strip is correspondingly equal to approximately 0.3 wavelengths. Moreever, to excite another resonant mode close to the 935-MHz operating frequency for broadband operation, the second branch strip (branch 2, from points A to D) is embedded between the input closed loop and branch strip 1. The strip's length of branch 2 is chosen to be about 105.5 mm and correspondingly equal to approximately 0.33 wavelengths of the 935-MHz band. Therefore, this proposed tag antenna with dual-branch strips can be considered as a half-wavelength dipole antenna. The electromagnetic simulator HFSS based on the finite element method [12] has been applied for the proposed tag antenna design to demonstrate the above deduction and guarantee the correctness of measured results. Also, the input impedance of the proposed tag antenna is measured on an Agilent Vector Network Analyzer 8722ES with two-port calibration kit N1020A.

III. Results and Discussion

Fig. 2 shows the related simulated and experimental results of the input impedance and return loss for the proposed broadband tag antenna of Fig. 1. The related results are listed in Table I for comparison. Results show the satisfactory agreement for the proposed broadband tag antenna design operating at the UHF band. First, due to this posting shorting pins and dual-branch dipole strips, two resonant modes can be coherently excited, but with high input impedance. Then, by adding the closed loop connected with the input ports, the input impedance significantly reduces to be easily matching with the input impedance of the IC chip to enhance the operating bandwidth for the RFID UHF band. For the realization of impedance matching between the tag antenna and IC chip, the half-power (3-dB return loss) bandwidth specification had been adopted in the presented designs [3], [4], [6], [9]. From the experimental results, the measured bandwidth ($RL \geqq 3$ dB) can reach about 112 MHz (850–962 MHz) for the UHF band, which totally covers the worldwide RFID UHF band.

To fully comprehend the excitation of the RFID UHF band, the surface current distributions at 880 and 935 MHz are illustrated in Fig. 3, along with an additional arrow mark showing the path lengths of dual resonant modes. For the 880-MHz mode, the surface current length $(\mathrm{A} \rightarrow \mathrm{B} \rightarrow \mathrm{C})$ is about 103.5 mm and correspondingly equal to approximate 0.3 wavelengths of this first operating mode. Due to the shorting pins posted at the corner of the broadband tag antenna, which is close to point B,

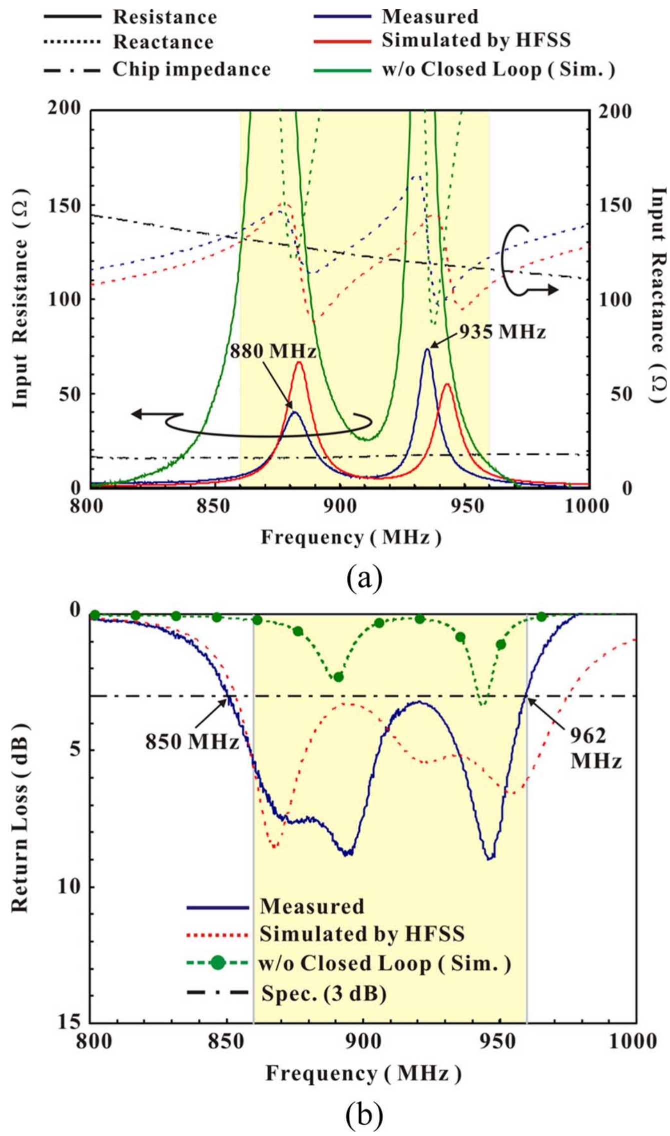

Fig. 2. Simulated and measured input impedance and return loss against frequency for the proposed broadband tag antenna. Antenna parameters are given in Table I. (a) Input impedance. (b) Return loss.

TABLE I
Simulated and Measured Return Loss Against Frequency for the Proposed Broadband Tag Antenna. $L1 = 32$ mm, $L2 = 27$ mm, $h = 3$ mm

The proposed tag antenna	$f_L \sim f_H$ (MHz)	BW (MHz / %)
Measured	850 ~ 962	112 / 12.1
Simulated	853 ~ 975	122 / 12.2

the surface current distribution is seriously disturbed to shift the operating frequency from 575 to 880 MHz. For the 935-MHz resonant mode, a relatively stronger excited surface current distribution with 0.33-wavelength operation along branch strip 2 $(\mathrm{A} \rightarrow \mathrm{B} \rightarrow \mathrm{D})$ is illustrated in Fig. 3(b).

Fig. 4 shows the experimental results of input impedance for the proposed broadband tag antenna of Fig. 1 with the shorting pins or not. It is easily found that the first UHF operating band can be shifted from 575 to 880 MHz due to the surface current

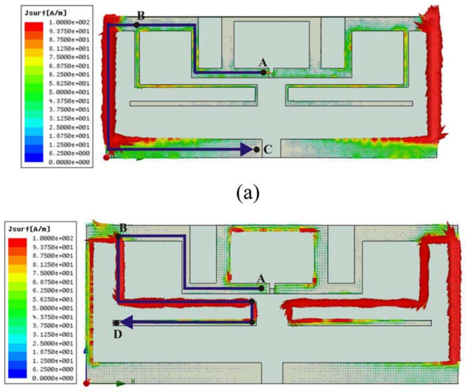

Fig. 3. Simulated surface current distributions for the proposed broadband tag antenna shown in Fig. 1. (a) $f = 880$ MHz. (b) $f = 935$ MHz.

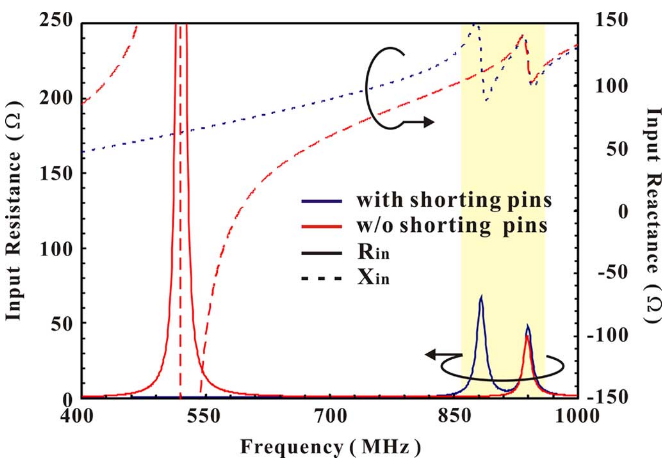

Fig. 4. Measured input impedance for the proposed broadband tag antenna with the shorting pins or not. Other antenna parameters are given in Table I.

distribution on the tag antenna and the back metal plate, which is tremendously disturbed by the shorting pins. On the other hand, the resonant modes near the 935-MHz band can be invariantly excited. In addition, by properly adjusting the height (h) between the planar broadband tag antenna and the back metal plate, the simulated input impedance of the proposed tag antenna can be obtained, as shown in Fig. 5. On account of the capacitive effect, it is easily seen that as the height (h) increases, the input impedance also increases to make the operating frequencies of dual resonant modes shift higher.

The measured return loss for the proposed broadband tag antenna with various lengths (L_1) of branch strip 1 is illustrated in Fig. 6. It can be observed that when the strip's length of L_1 increases from 31 to 33 mm, the surface current path $(\mathrm{A} \rightarrow \mathrm{B} \rightarrow \mathrm{C})$ also increases to make the operating frequency of the first resonant mode significantly decrease as the inductive effect increases. However, the second resonant mode near 935 MHz is less varied. Also, the measured input impedance of the proposed tag antenna with various lengths (L_2) of branch strip 2 is illustrated in Fig. 7. When the strip's length of L_2 increases from 25 to 28 mm, the surface current path $(\mathrm{A} \rightarrow \mathrm{B} \rightarrow \mathrm{D})$ also increases to make the operating frequency of the second resonant mode significantly decrease as the first resonant mode near the

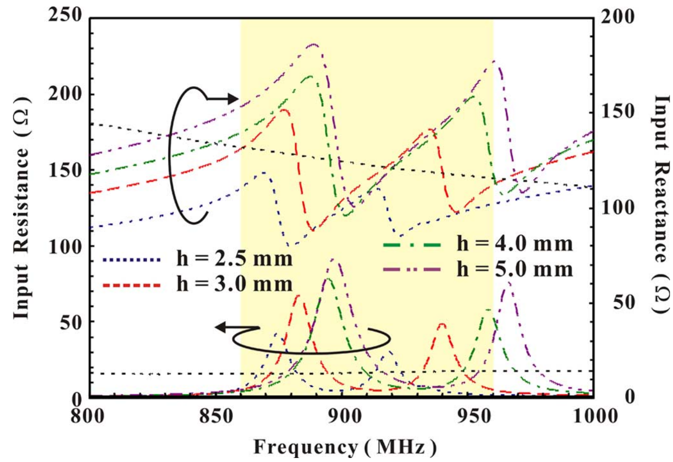

Fig. 5. Simulated input impedance for the proposed broadband tag antenna with various height between the antenna and the back metal plate. Other antenna parameters are given in Table I.

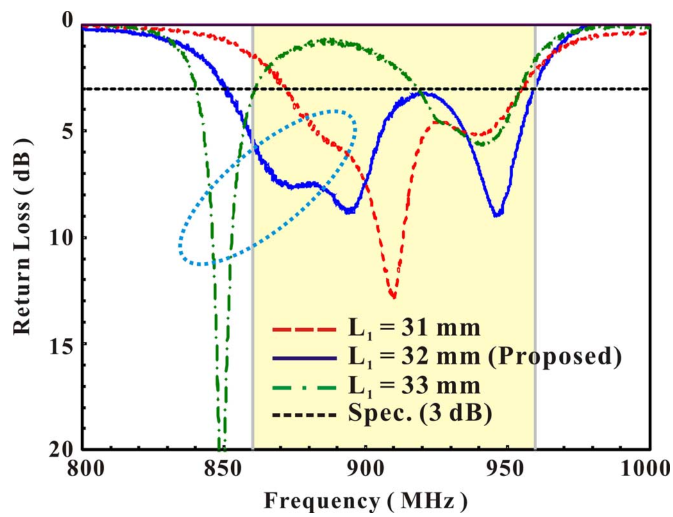

Fig. 6. Measured return loss for the proposed broadband tag antenna with various lengths (L_1) of the branch strip 1. Other antenna parameters are given in Table I.

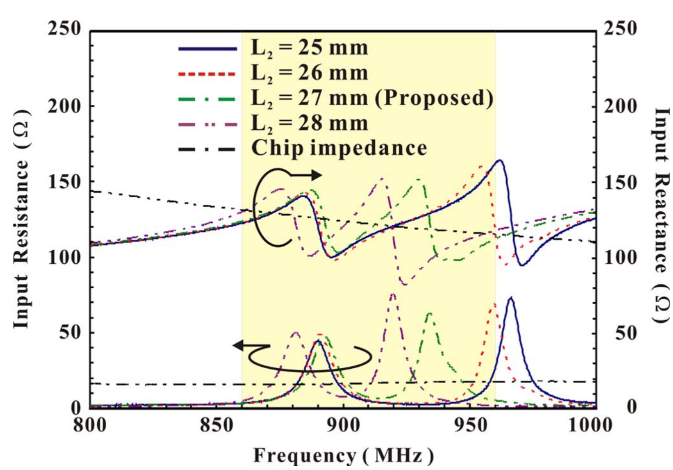

Fig. 7. Measured input impedance for the proposed broadband tag antenna with various lengths (L_2) of the branch strip 2. Other antenna parameters are given in Table I.

880-MHz band is less varied. Fig. 8 shows the comparison of the simulated return loss for the proposed tag antenna attached on

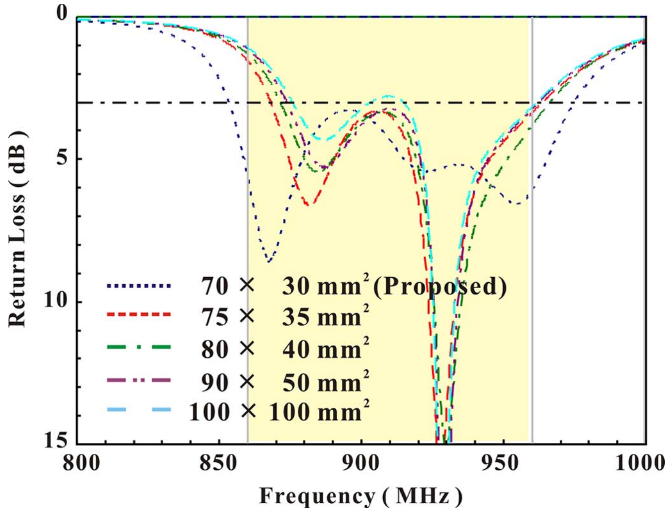

Fig. 8. Simulated return loss for the proposed broadband tag antenna with various dimensions of the back metal plate. Other antenna parameters are given in Table I.

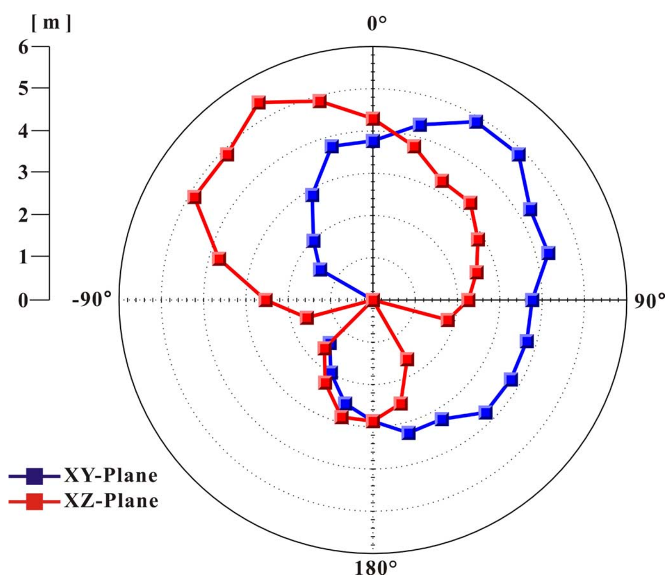

Fig. 9. Measured reading range patterns in the xy- and xz-planes for the proposed broadband tag antenna operating at 900 MHz.

various metallic objects with different sizes to realize the performance sensitivity to the ground plane size. It is found that the operating frequency is less sensitive of the metallic object's sizes to make this proposed tag antenna have more applications.

Based on the backscattering method, the dynamic measurement of the broadband tag antenna connected with the microchip is carried out in anechoic chamber by introducing the Tagformance lite Measurement System from Voyantic Company. A commercial UHF RFID reader with the output power of EIRP 4 W was connected to the CP antenna with a peak gain of 8 dBic. The measured 2-D reading patterns in the xy- and xz-planes of the planar broadband tag antenna are plotted in Fig. 9. It is easily found that the reading patterns are displayed with good unidirectional radiation patterns in the xy- and xz-planes with the maximum reading distance of 5.2 m, which in particular is caused by the effect of the surface current distribution concentrated around the shorting pins, and the maximum reading distance is tilted at $\theta = \pm 45^\circ$. Additionally, it is found the difference between the front and back reading ranges is about 2.2 m due to the back metal plate functions as the reflector.

IV. Conclusion

A novel broadband design of a planar tag antenna for the UHF RFID system has been proposed. By employing the shorting pins at the corner of this proposed tag antenna, dual resonant modes are closely excited to achieve broadband operation. The obtained impedance bandwidth across the operating band can reach about 112 MHz (12.5%) for the UHF band, which is from 850 to 962 MHz. Also, with unidirectional reading pattern, the measured reading distance is about 5.2 m as the proposed tag antenna mounted on the metallic object.

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