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BANDWIDTH ENHANCEMENT DESIGN OF PLANAR F-SHAPED TAG ANTENNA WITH PARASITIC STRIPS

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Abstract—A novel bandwidth enhancement design of planar F-shaped dipole antenna for RFID tag is proposed. With the use of two parasitic strips inset along the closed loop of the input IC chip in this proposed tag antenna, a new resonant mode close to 900 MHz band is excited to enhance the operating bandwidth. The obtained impedance bandwidth across the operating band can reach about 104 MHz for UHF band. With omni-directional reading pattern, the measured reading distance is about 2.8 m as the tag antenna mounted on the glass object.

1. 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 identification possible at frequency bands of 125 kHz (LF), 13.56 MHz (HF), 860–960 MHz (UHF) and 2450 MHz (Microwave). Recently, UHF (860–960 MHz) band RFID system becomes more attractive for many industrial services because it is able to provide longer reading distance, fast reading speed, and large information storage capability. In RFID

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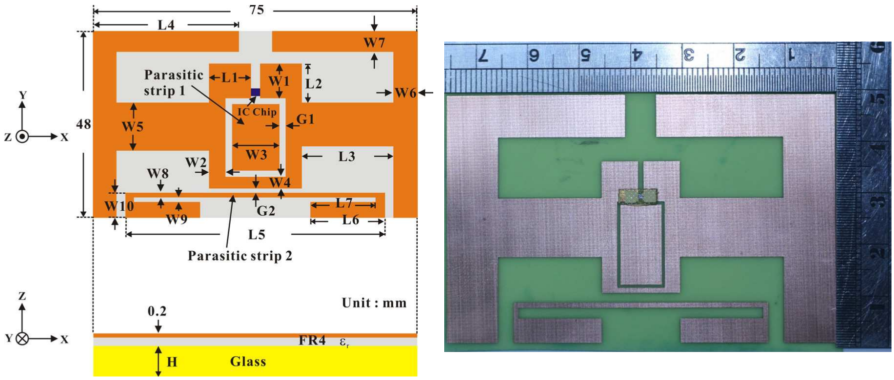
systems, tags are usually attached to objects having various material properties. Antenna is the key factor for RFID tag to transmit/receive the modulated information. The detection range and accuracy are directly dependent on the performance of reader/tag antennas. Some tag antennas for UHF RFID system have been proposed using planar unsymmetrical antenna [2], symmetrical dipole antenna [3–6], meander antenna [7] and slit antenna mounted on metal materials [8, 9]. However, tag antenna applied for the glass object of the car is very scant in the literature. And, to meet the operating band specification of UHF RFID system in any country and to overcome the operating frequency shifting and impedance variations due to the manufacturing process errors, the broadband tag antenna becomes much needed. Therefore, in this paper, we present a novel broadband design of UHF RFID tag antenna with omni-directional reading pattern. This RFID tag antenna (TA) is composed of F-shaped dipole with two parasitic strips and will be mounted on glass object of the car. Owing to the inset parasitic strips along the closed loop of the input IC chip in this proposed F-shaped tag antenna, a new resonant mode can be excited with two good matching modes to the input impedance of the IC chip. A new matching mode close to the fundamental matching mode of the regular F-shaped dipole antenna is obtained to make the impedance bandwidth reach about 104 MHz, which totally covers the worldwide RFID UHF band. With omni-directional reading pattern, the maximum reading distance is about 2.8 m as the tag antenna mounted on the glass object. Details of the proposed UHF RFID tag antenna designs are described, and experimental results for the obtained performance operated at 900 MHz band are presented and discussed.

2. ANTENNA DESIGN AND RESULTS

As shown in Figure 1, two parasitic strips are inset along the closed loop of the input IC chip in this proposed F-shaped tag antenna mounted on glass object of the thickness, H. The overall antenna size of $75(L) \times 48(W)\,\mathrm{mm}^2$ is etched on an inexpensive FR4 substrate with the substrate of thickness h (0.2 mm) and relative permittivity ε_r (4.7). The impedance of the microchip (Higgs-2), which is connected between two feed points of the closed loop, is (17–j120) Ω at the operating frequency of 925 MHz in this study. First, to decrease the input inductance of the regular F-shaped dipole antenna the rectangular parasitic strip 1 is introduced to be inset in the closed loop. And, for achieving the resonant mode close to 900 MHz band the parasitic strip 2 is parallel inset along the lower edge of the closed



(a) Geometry (b) Photo

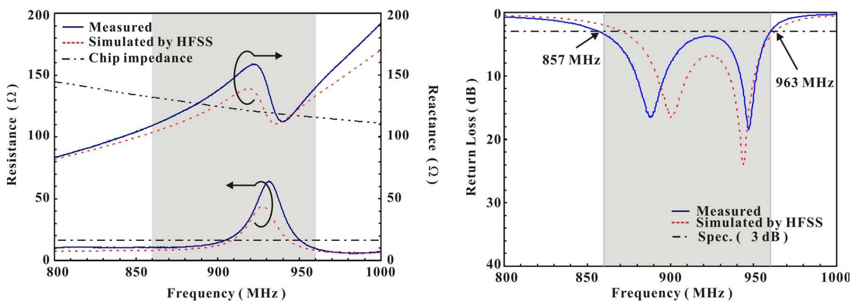
Figure 1. Geometry and photo of the proposed F-shaped tag antenna mounted on glass object for RFID system.

loop to make the surface current length chosen to be about 80.5 mm corresponding approximately to 0.25 wavelengths of 925 MHz bands Due to the presence of the inset two parasitic strips, the resonant mode of the regular F-shaped dipole antenna is significantly decreased to be operated at UHF band to enhance the operating bandwidth for RFID system.

To demonstrate the above deduction and guarantee the correctness of simulated results, the electromagnetic simulator HFSS based on the finite element method [10] has been applied for the proposed tag antenna design. The input impedance of the proposed antenna is measured on an Agilent Vector Network Analyzer 8722ES with two-port calibration kit N1020A. Figure 2 shows the related simulated and experimental results of the input impedance and return loss for the proposed F-shaped tag antenna of Figure 1. The related results are listed in Table 1 as comparison. Results show the satisfactory agreement for the proposed tag antenna design operating at UHF bands. Due to the two inset parasitic strips along the closed loop of the input IC chip in this proposed F-shaped dipole antenna, a new resonant mode can be excited to have good matching with the input impedance of the IC chip. Therefore, it is found that a new matching mode close to the fundamental matching mode of the regular F-shaped dipole antenna is obtained to enhance the operating bandwidth for 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 proposed designs [3, 9]. From the experimental results, the measured bandwidth

Table 1. Simulated and measured return loss against frequency for the proposed F-shaped tag antenna; $\varepsilon_r = 4.7$, $h = 0.2\,\text{mm}$, $L_1 = 10\,\text{mm}$, $L_2 = 7.2\,\text{mm}$, $L_3 = 20\,\text{mm}$, $L_4 = 35\,\text{mm}$, $L_5 = 48\,\text{mm}$, $L_6 = 17\,\text{mm}$, $L_7 = 16\,\text{mm}$, $W_1 = 8\,\text{mm}$, $W_2 = 3\,\text{mm}$, $W_3 = 9\,\text{mm}$, $W_4 = 1\,\text{mm}$, $W_5 = 11.5\,\text{mm}$, $W_6 = 10\,\text{mm}$, $W_7 = 8\,\text{mm}$, $W_8 = 1\,\text{mm}$, $W_9 = 2\,\text{mm}$, $W_{10} = 7.7\,\text{mm}$, $G_1 = 0.5\,\text{mm}$, $G_2 = 2.5\,\text{mm}$, $H = 15\,\text{mm}$.

The proposed tag antenna	$f_L \sim f_H$ (MHz)	BW (MHz/%)
Simulated	871 ~ 963	92 / 10
Measured	857 ~ 961	104 / 11.4

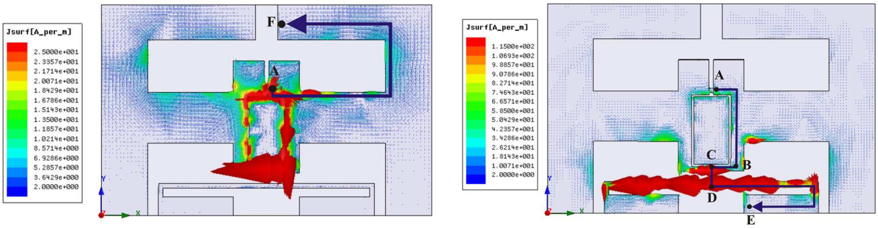


(a) Input impedance (b) Return Loss

Figure 2. Simulated and measured input impedance and return loss against frequency for the proposed F-shaped tag antenna mounted on glass object; antenna parameters are given in Table 1.

($RL \geq 3\,\text{dB}$) can reach about 104 MHz for UHF band, which totally covers the worldwide RFID UHF band.

To fully comprehend the excitation of RFID UHF bands, the surface current distributions at 880 and 948 MHz are illustrated Figure 3, along with an additional blue arrow sign showing the path length of the matching modes For 880 MHz mode, the surface current length of the F-shaped dipole antenna (A $\rightarrow$ F) is about 84.8 mm corresponding approximately to 0.25 wavelength of the operating mode As for 948 MHz mode, a quarter wavelength distribution along the closed loop coupling to the parasitic strip to have an effective path (A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ D $\rightarrow$ E) is observed Figure 4 shows the comparison of the simulated impedance for the proposed F-shaped dipole antenna with the parasitic strips or not. Owing to the parasitic strip 1 inset around the input closed loop, the capacitance can be generated to lower the input inductance of the proposed tag antenna. And, by more introducing the parasitic strip 2 close to the lower edge of the closed loop, more capacitive effect can be obtained to improve impedance



(a) f = 880 MHz (b) f = 948 MHz

Figure 3. Simulated surface current distributions for the proposed F-shaped tag antenna.

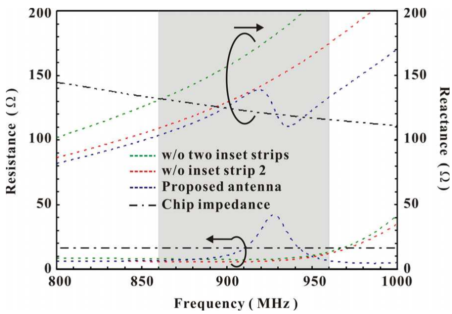
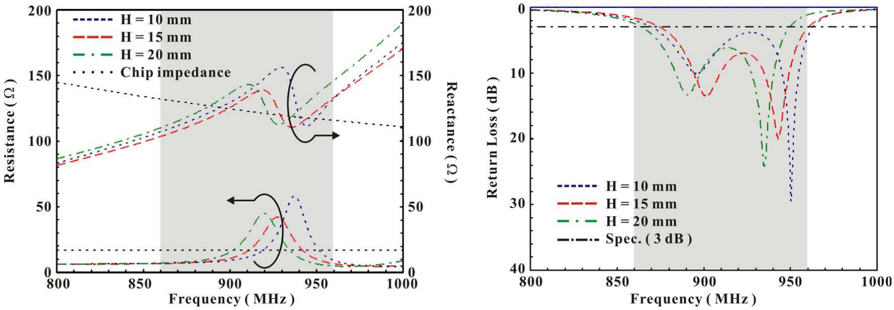


Figure 4. Comparison of simulated impedance against frequency for the proposed F-shaped tag antenna with the parasitic strips or not; other antenna parameters are given in Table 1.

matching of the proposed tag antenna.

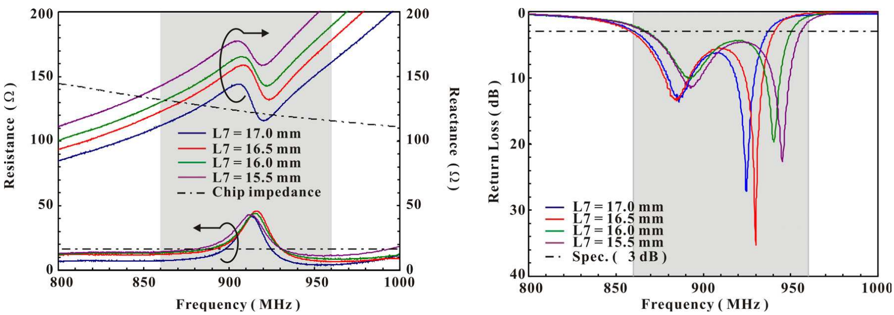
To meet the future application in automobile, the impedance characteristics of the proposed F-shaped dipole antenna against various thickness of the glass object have been discussed. Figure 5 shows the simulated impedance and return loss for the proposed F-shaped dipole antenna against the variation of the glass thickness. Probably due to the loading effect of the glass, it can be easily found that the resonant frequency slightly decreases with the glass thickness increased to obtain the operating frequency less sensitive of the the glass thickness. Therefore, to overcome the operating frequency shifting and impedance variations due to the variation of the glass thickness, this proposed broadband tag antenna can provide much need for the practical application.

The measured impedance and return losses for the proposed F-shaped tag antenna with various slit lengths (L_7) of the parasitic strip 2 is illustrated in Figure 6. It can be found that when the slit length of



(a) Input impedance (b) Return Loss

Figure 5. Simulated impedance and return loss for the proposed F-shaped tag antenna with various thickness of the glass object; other antenna parameters are given in Table 1.

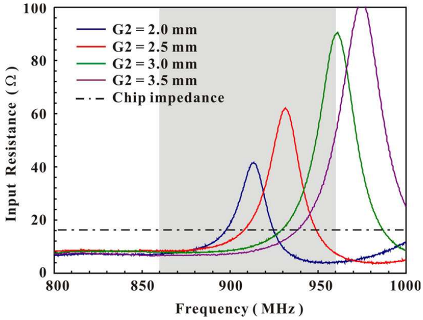


(a) Input impedance (b) Return Loss

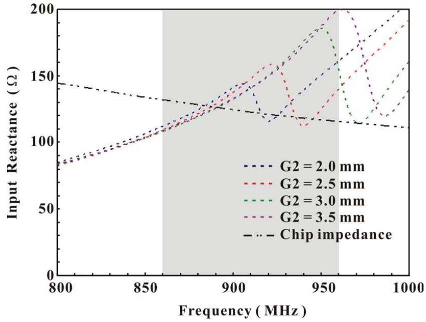
Figure 6. Measured impedance and return loss for the proposed F-shaped tag antenna with various slit lengths of the parasitic strip 2; other antenna parameters are given in Table 1.

L_7 decreases from 17 mm to 15.5 mm, the surface current path ($A \rightarrow B \rightarrow C \rightarrow D \rightarrow E$) also decreases to make the operating frequency of second matching mode significantly increased with the capacitive effect decreased. And, by properly adjusting the gap (G_2) between the closed loop and the parasitic strip 2, the measured impedance and return loss for the proposed F-shaped tag antenna is shown in Figure 7. Due to the coupling capacitive effect more vanishing, it is easily found that the impedance increases with the gap increased to make the operating frequency of the new (second) matching mode increased.

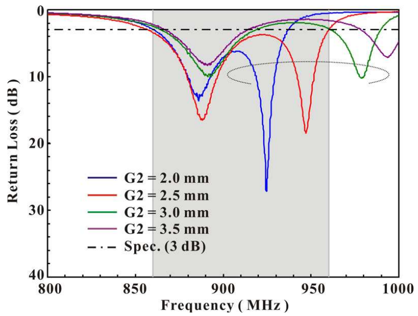
Based on the backscattering method, the dynamic measurement of the tag antenna with the microchip is carried out in anechoic chamber by introducing Tagformance lite Measurement System from



(a) Input resistance

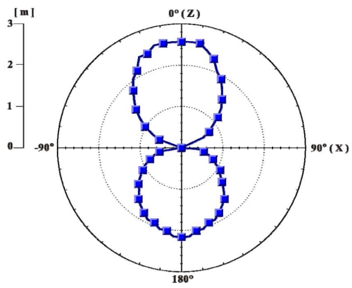


(b) Input reactance

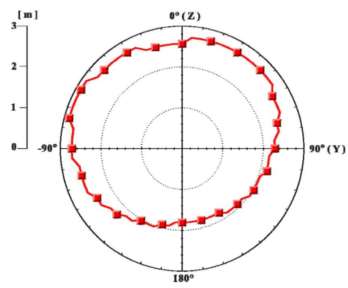


(c) Return Loss

Figure 7. Measured impedance and return loss for the proposed F-shaped tag antenna with various gaps between the closed loop and the parasitic strip 2; other antenna parameters are given in Table 1.



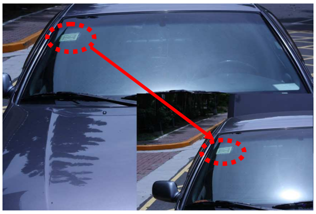
(a) XZ plane



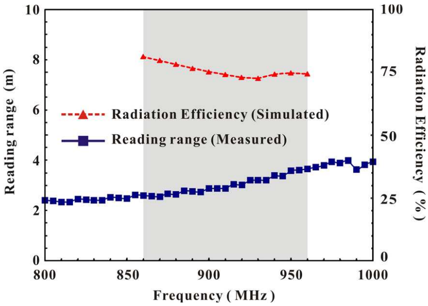
(b) YZ plane

Figure 8. Measured XZ plane and YZ plane reading range patterns for the proposed planar tag antenna operating at 925 MHz.

Voyantic Company. A commercial UHF RFID reader with the output power of EIRP 3.28 W was connected to the CP antenna with peak gain of 8 dBic. The measured 2D reading patterns in XZ and YZ



(a) Tag mounted on the automotive front glass



(b) Reading range and radiation efficiency

Figure 9. Measured reading range and simulated radiation efficiency across the operating frequencies for the proposed F-shaped tag antenna.

planes of the planar F-shaped tag antenna mounted on the glass are plotted in Figure 8. It is easily found that the patterns are with good omni-directional radiation pattern in the YZ plane and broadside radiation in the XZ plane with the maximum reading distance of 2.8 m. Probably due to the loading effect of the glass object, the reading distance at $-Z(\theta = 180°)$ direction is less than that at $+Z$ $(\theta = 0°)$ direction.

To clearly realize the practical application, the dynamic measured system is installed in the outdoor by the proposed F-shaped tag antenna attached on the automotive front glass shown in Figure 9(a) communicated with a commercial UHF RFID reader mentioned above. The measured reading range and simulated radiation efficiency across the operating frequencies are shown in Figure 9(b). The maximum measured reading range is about $2.5 \sim 3.1$ m. The measured results are close to the experimental data by the Tagformance lite Measurement System in anechoic chamber. And, the simulated radiation efficiency of the proposed F-shaped dipole antenna is about $73 \sim 80\%$ across the operating frequencies with antenna gain of 2.3 dBi, which is close to that of the conventional dipole antenna.

3. CONCLUSION

A novel design of planar tag antenna with bandwidth enhancement for RFID system has been proposed. By insetting two parasitic strips along the closed loop of the input IC chip in this proposed tag antenna, a new resonant mode close to 900 MHz band is excited to have second matching mode close to the first matching mode of the regular F-shaped dipole antenna for enhancing the operating bandwidth due to the capacitive effects. The obtained impedance bandwidth across the operating band can reach about 104 MHz for UHF band. With omni-directional reading pattern, the measured reading distance is about 2.8 m as the tag antenna mounted on the glass object of the car.

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