Design of active and passive license plate tag antenna for vehicle RFID system

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1. Introduction

The radio frequency identification (RFID) system is growing with many promising features in wireless communication technology application, especially in the UHF band for its suitability of communication link between a reader and many tags [1]. This technology is useful for the near field communication zone. An auto vehicle RFID system is a good candidate for various application such as transit fare, parking-lot fees, pay on tollgate fees and so on [2~3]. Most of the car entrance and exit control systems can meet easily at the gateway barriers in resident apartments, tall building and so on. It took a long time to pass a gateway in conventional system because of manual control by person. Recently, it can reduce the gateway pass time because of automatic control by RFID system replace with person. The important consideration items in tag antenna design are identification ratio, readable range and change of the resonant frequency according to the attached materials. In order to improve the identification accuracy, dual resonant frequency diversity design is conducted. It can definitely reduce the error of identification ratio comparison with one tag antenna system relatively. Active and passive antennas are designed dipole configuration with symmetrical structure to improve the bandwidth characteristics and the increase of readable range in this paper.

2. Design of tag antenna

Fig. 1 shows the design structure of proposed tag antenna considered the vehicle bumper of polyurethane. It is composed of aluminum metal antenna plate as license plate, volts and nuts, and a part of vehicle bumper made by polyurethane. The aluminum plate and the polyurethane bumper are fixed by the volts and nuts. Even though the kinds of Korea license plate size are various, the considered standard plate size in design is 335 mm X 155 mm X 1 mm. A substrate and a chip impedance in design are ε_r= 6.5 and 16 - j131 Ω, respectively. The input impedance of tag antenna is matched to 16 + j131 Ω for the maximum transmission power. In reference [4], the characteristics of license plate antenna such as resonant frequency shifting and radiation pattern change by the bumper size and the dielectric permittivity of polyurethane as well as the volts and nuts were analyzed and measured. License plate antenna has dual resonant frequency of active (433.92 MHz) and passive (900 MHz) tag band to reduce identification error. Fig. 2 shows the calculated return loss of slot length variation of L1 operated at the active tag antenna band. According to the variation of L1, the resonant frequency changes. When the L1 is over 61 mm, resonant frequency is not shifted anymore and the return loss is not almost changed. Because aluminum plate with slot is operated as active tag antenna. Fig. 3 shows the calculated return loss by L2 variation of U-shaped passive antenna. The calculated isolation level between active and passive tag antenna appears -20 dB below at the interested bands at L2 = 70 mm. The calculated resonant frequency and bandwidth are 900 MHz and 110 MHz (850 ~ 960 MHz) at -10 dB below, respectively. These results satisfy the specifications required at the UHF RFID system. Recently, UHF RFID reader equipments for apartments and tall building gateway application are established at both sides of vehicle passway. Therefore, beam direction of license plate antenna has to cover up to ± 90 degrees ranges. As shown in Fig. 4 (a), because half beam width is above ± 60 degrees, beam directions cover the both sides as well as front of vehicle up to ± 60 degrees. Because radiation pattern at 900 MHz is toward ± 90 degrees as shown in Fig. 4 (b), reader equipments located on right and left side of the gateway are covered by the beam.

3. Measurement results

Fig. 5 shows a fabricated antenna photograph. The simulated and measured return loss values of tag antenna are shown in Fig. 6. For practical measurement of the fabricated antenna, a port with transmission line impedance of 50 Ω is used, even though tag antenna with 16 + j131 Ω considered the complex conjugate impedance of the chip impedance is designed. Because the input/output port impedance value of transmission line used in the RF measuring instrument is generally 50 Ω. Therefore, tag antenna with 50 Ω instead of 16 + j131 Ω is re-designed for antenna measurement. As shown in the Fig. 6, the measured return loss and isolation of the fabricated antenna with 50 Ω are shown the good agreement with the calculated results of the re-designed tag antenna with 50 Ω. To prove the objective validity of tag antenna design with 16 + j131 Ω, the measured impedance values with 50 Ω are changed by impedance transformation equation [5]. The transformed return loss and isolation of active and passive antenna are also observed the reasonable agreements with the calculated ones with impedance of 16 + j131 Ω. Fig. 7 shows comparison of the calculated and measured radiation pattern of the fabricated antenna with 50 Ω at 2.3 GHz and 2.7 GHz, respectively. As shown in Fig. 7, the measured radiation pattern is also shown the good agreement with results of the calculated antenna as shown in Fig. 4. Fig. 8 shows the measured readable range of the proposed tag antenna with volts and nuts, and polyurethane. In order to measure the readable range and angle, the chip with 16 - j131 Ω is connected at feed position of tag antenna in Fig. 5. These ranges and angles are measured by display identification of commercial reader system which has circularly polarized patch antenna with gain of about 6 dBi. This equipment system are installed in an anechoic chamber to prevent the jamming and interference wave from outside. The 0 degree in Fig. 8 means the front direction that tag antenna and reader antenna stand opposite to each other. On the other hand, the 90 degrees indicate the perpendicular direction with respect to the above front direction. It means that tag antenna is rotated 90 degrees in the azimuth direction when reader antenna is fixed. The maximum readable range of the fabricated tag antenna is observed 9.5 m (only antenna) and 8.5 m (antenna with volts, nuts, and polyurethane) in front direction. It is observed that the readable range of the fabricated tag antenna involved in volts, nuts, and polyurethane is shorter than one of only antenna. Because of the impedance change according to the materials of the aluminum and polyurethane, it is observed the distance change of the maximum readable range.

4. Conclusion

This paper describes a design of active and passive license plate tag antenna for vehicle RFID system. The commercial chip impedance considered in design is 16 - j131 Ω and the complex conjugate impedance of chip is used as input impedance of tag antenna. The measured return loss, isolation between active and passive antenna structure and radiation pattern are showed reasonable agreement with the calculated results. The measured readable range was about 8.5 m at the front of a reader antenna and this distance is longer than the average readable range of commercial tag antenna.

5. Figures

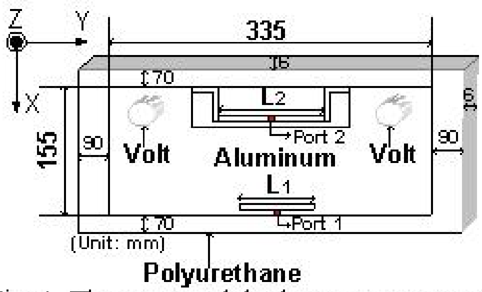


Fig. 1. The proposed dual tag antennas structure.

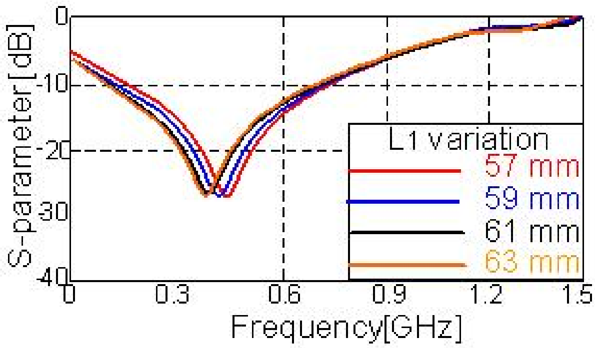


Fig. 2. Variation of return loss by L1.

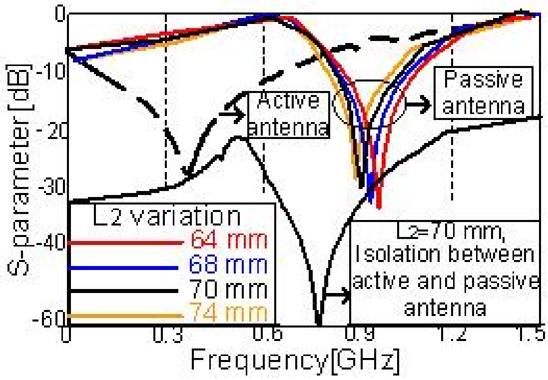
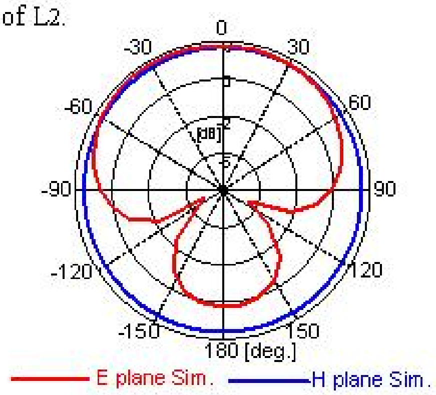
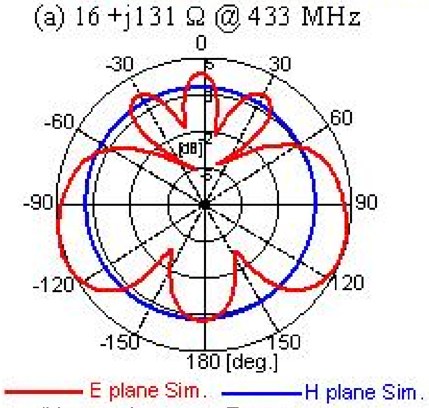


Fig. 3. Comparison of parameters by length variation of L2.



(a) 16 +j131 Ω @ 433 MHz



(b) 16 +j131 Ω @ 900 MHz

Fig. 4. The calculated radiation patterns at 433 MHz and 900 MHz.

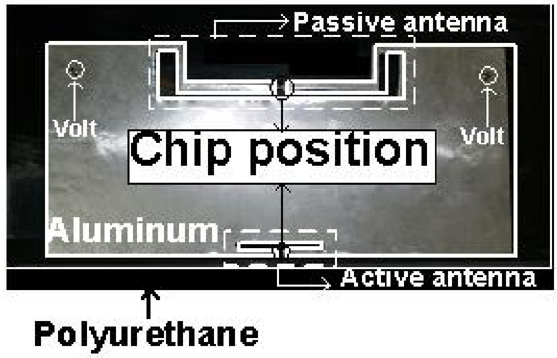
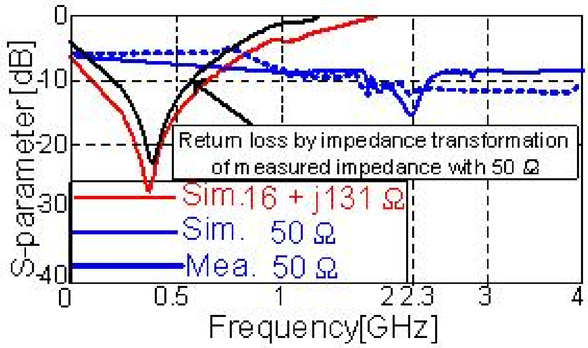
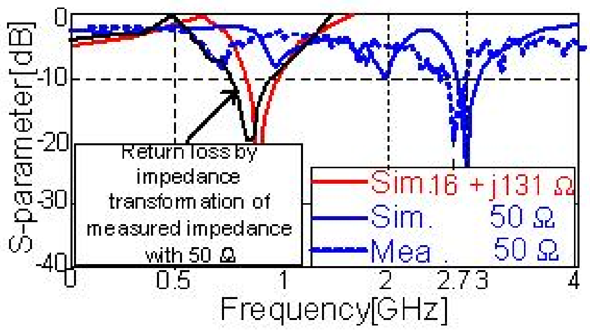


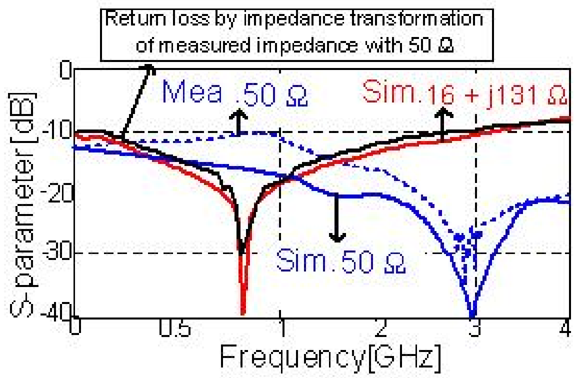
Fig. 5. Photo of the fabricated license plate with volts, nuts, and polyurethane.



(a) Return loss of active antenna

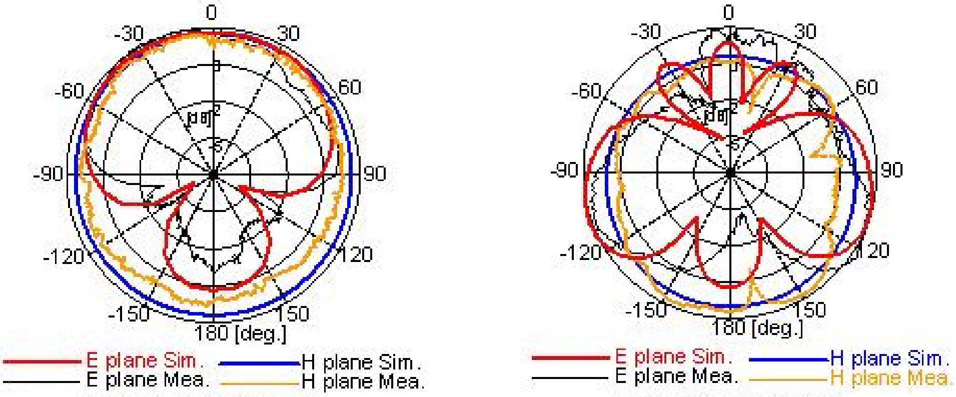


(b) Return loss of passive antenna



(c) Isolation between active and passive antenna

Fig. 6. The simulated and measured return loss of active and passive antenna.



(a) 50 Ω @ 2.3 GHz (b) 50 Ω @ 2.7 GHz

Fig. 7. The simulated and measured radiation pattern of 50 Ω fed tag antenna with volts, nuts and polyurethane.

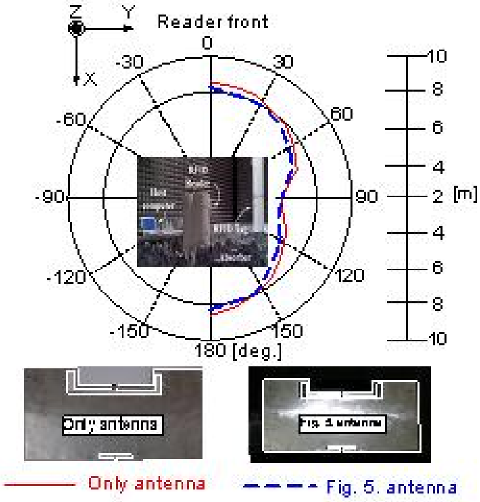


Fig. 8. Comparison of the measured readable range by angle.

Acknowledgments

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