RFID Tag Antennas Design for Closely Located and High Dielectric Objects

陳 冠華, 陳 強 (東北大学大学院工学研究科)

Abstract: The power transmission ratio between the radio frequency identification (RFID) tag and the chip is important in the tag antenna design. The tag used in the near field communication is affected by the monitored objects and the other tags nearby. In this report, a tag antenna which is suitable to the close location and the the high permittivity objects is proposed to obtain high power transmission ratio between the RFID tag antenna and the chip.
Keyword: Radio frequency identification (RFID), Tag antenna, Ultra high frequency (UHF)

1. Introduction

In recent years, RFID is one of the most promising technologies for wireless identification system and sensor network system [1][2]. It is applied in retail store, security, electronic wallet, and so on. The RFID tag can be attached on an object and used to track inventory and assets [3].

One of the applications using RFID system is the goods management [4]. A reader antenna is put on desks or shelves and the tag attached objects are put on it to be monitored. It can be applied to warehouses or libraries to manage items in real time and the management efficiency is increased.

However, there are two technical problems in this system. First, the monitored objects are thin and located closely such as books and documents in the library. The mutual coupling between two tags affects the performance of it. Second, the tag attached object has high permittivity such as glasses and ceramics in the deportment store are also affect the tag. In those situations, the mismatching between the RFID tag antenna and the chip could happen and cause the tag cannot be detected. Therefore, RFID tags which can be operated in close location and attached on objects with high permittivity are required.

In this report, an UHF RFID tag antenna which has good resistance to the influence of other objects nearby is proposed. It has better performance when the tag is near the other tag or attached on objects with high relative permittivity. Numerical simulation of the proposed methods is performed using the method of moments, and the increase of power transmission ratio are demonstrated.

2. Definition

A RFID tag consists of an antenna and a chip. It can be considered as an one-port network circuit [5] and the equivalent network circuit is shown in Fig. 1. The circuit represents a generator-load circuit with a complex source and a load impedance, where Z_l is the load impedance, Z_s is the internal impedance of the voltage source, and $V_s$is the source voltage.

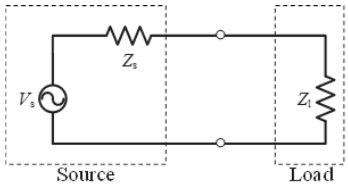

Figure 1: Generator-load network circuit.

The power wave reflected from the load back to source can be defined as the power wave reflection ratio Γ

$$\Gamma = \frac{Z_l - Z_s^*}{Z_l + Z_s} \tag{1}$$

and the power reflection ratio $|\Gamma|^2$ shows the ratio of the maximum power available from the source is not delivered to the load.

$$|\Gamma|^2 = \left| \frac{Z_l - Z_s^*}{Z_l + Z_s} \right|^2, 0 \leq |\Gamma|^2 \leq 1 \tag{2}$$

The power transmission ratio t can be written as

$$t = 1 - |\Gamma|^2, 0 \leq t \leq 1 \tag{3}$$

It is demonstrated that the load impedance Z_l and the source impedance Z_s must be conjugate matched to achieve the maximum power transmit to the load. In this report, the power transmission ratio is used to evaluate the input power to the tag chip.

3. Tag Antenna Design and Evaluation

3.1 Planar Dipole antenna

An UHF RFID tag is designed to have small size and the input impedance of the tag antenna should be conjugate matched to the chip impedance to achieve the maximum power transmission ratio. A planar diploe antenna is designed for UHF RFID system as shown in Fig. 2, where l_a = 90 mm and w_a = 17 mm. It is designed to conjugate match to the RFID chip [6].

The impedance of the chip at 920 MHz with -13 dBm incident power is $7.2 - j156.5\ \Omega$. The input impedance of the tag antenna and the power transmission ratio between the chip and the antenna are shown in Fig. 3 and 4, respectively. It is demonstrated that the input impedance of the planar dipole antenna and the chip impdeance are conjugated and the power transmission ratio is achieved to maximum value around 920 MHz.

In some applications of RFID system, the RIF tags are attached on the thin object located closely. In this situation, the tags are easuly influenced by the tag nearby. The simulation moedl of two tags close to each other is

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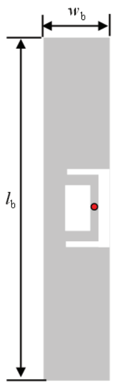

Figure 2: Geometry of planar dipole antenna.

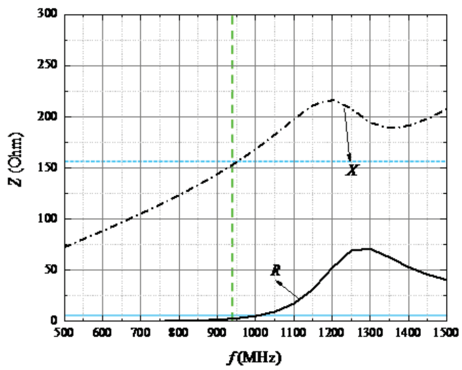

Figure 3: Input impedance of the planar dipole antenna.

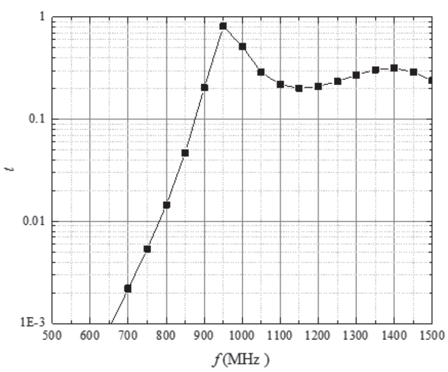

Figure 4: Power transmission ratio of dipole antenna between planar dipole antenna and chip.

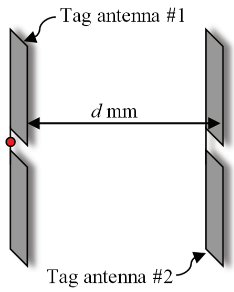

Figure 5: Simulation model of two RFID tags located closely.

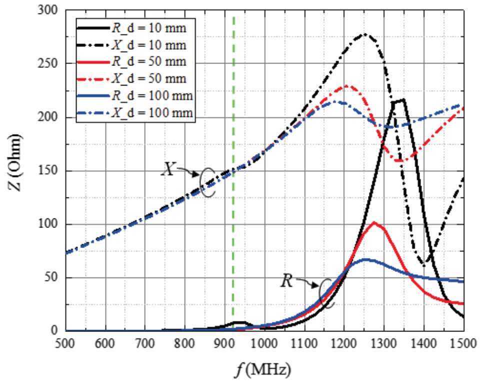

Figure 6: Input impedance of planar dipole antenna located closely.

shown in Fig. 5. The distance between two tags are varied from 1 to 10 mm. The method of moments is applied to analyze the simulation models.

The variation of the input impedance and the power transmission ratio between the antenna and the chip are shown in Fig. 6 and Fig. 7, respectively. It is shown that the input impednace of the tag antenna is affected by the other tag located closely and resonance frequency becomes low. It is demonstrated that the tag antenna is influenced by the other tag especially when the tags are extremely closed to each other.

In other application, the RFID tags are attached on the objects with high relative permittivity which influence the input impednace of the tag antenna. The simulation model of the planar dipole antenna attached on a dielectric is shown in Fig. 8. The tag is attached on a cub and the relative permittivity ϵ_r is varied from 3 to 10.

The variation of the input impedance and the power transmission ratio between the antenna and the chip are shown in Fig. 9 and Fig. 10, respectively. It is demonstrated that the input impedance of the tag antenna is affected by the dielectric and the resonance frequency also becomes low. Therfore, the power transmission ratio is decreased due to the mismatch between the tag antenna and the chip.

In summary, the tag antenna should be designed after considering the effects of the dielectric and other tag nearby. The resonance frequency of the tag antenna must be set to higher frequency than usual.

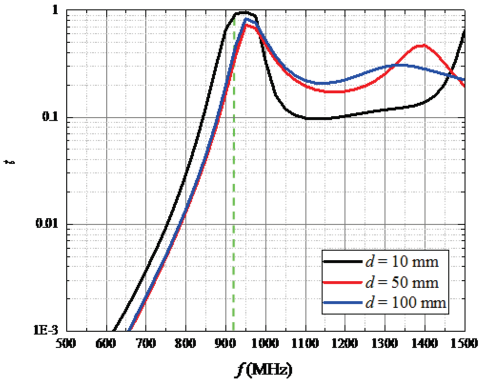

Figure 7: Power transmission ratio of planar dipole antenna located closely.

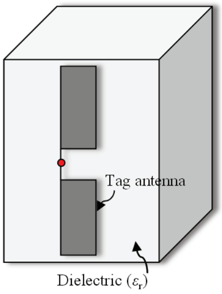

Figure 8: Simulation model of RFID tag attached on dielectric.

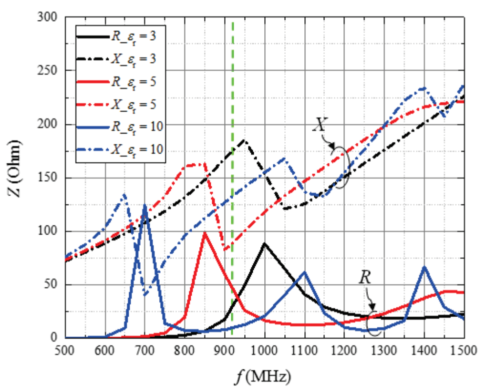

Figure 9: Input impedance of planar dipole antenna attached on dielectric.

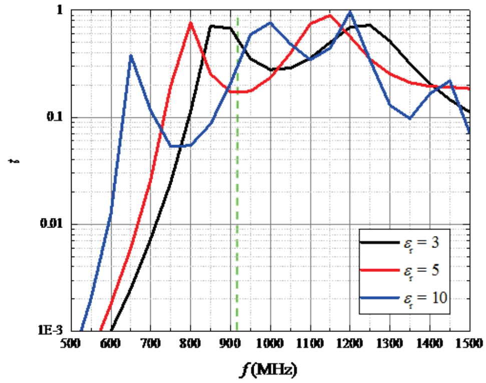

Figure 10: Power transmission ratio of planar dipole antenna attached on dielectric.

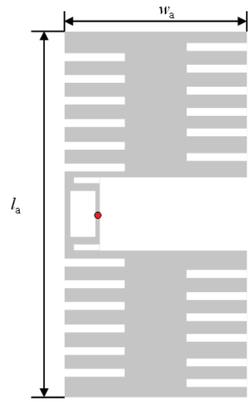

Figure 11: Geometry of proposed meander antenna.

3.2 Proposed Meander Antenna

Consiedering the situations of the RFID tags attached on the high dielectric object and located closely, the tag antenna should be modified to adjust the input impedance. In order to obtain the lower resonance frequency, the size of tag antenna is enlarged. However, the size of the tag antenna should be reduced to fit into the detected objects, a meander dipole antenna which is using the same chip impedance as the pervious one as shown in Fig. 11 is proposed, where $l_a = 100$ mm and $w_a = 50$ mm. The input imnpedance of the proposed meander antenna is shown in Fig. 12. It is demonstrated that the input impedance of the proposed antenna is smaller than the conjugated impedance of the chip in both real part and imaginary part.

The proposed meander antenna in both conditions of attched on a high dielectric object and located closely are analyzed by using method of moment and the simulation results are shown in Fig. 13 and Fig. 14, respectively. The black line and the red line show the input impedance of the planar dipole antenna and proposed meander antenna, respectively. The contour line shows the power transmission ratio between the chip and the antenna with different input impedance at 920 MHz.

Fig. 13 shows that the dipole antenna has higher power transmission ratio to the chip when the tag is far from the other one, but the proposed meander antenna has better power transmission ratio when the tag is close

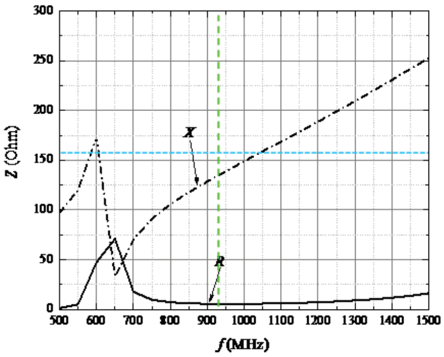

Figure 12: Input impedance of proposed meander antenna.

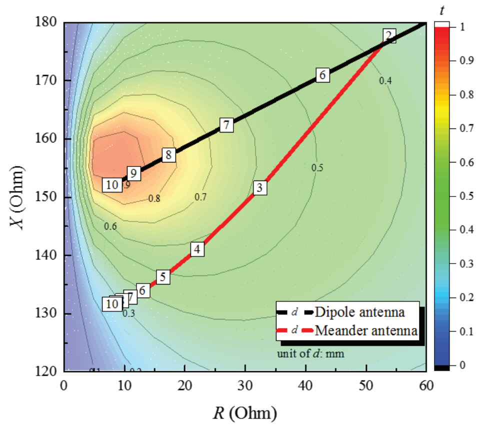

Figure 13: Power transmission ratio of two tags close to each other with different d.

to the other one. Fig. 14 shows that the dipole antenna attached on the dielectric has larger variations in the impedance. On the other hand, the meander antenna has better resistance to the dielectric. It is demonstrated that the proposed meander antenna has higher power transmission ratio when the tag closes to the other one or the tag is attached on the dielectric.

4. Conclusions

In some applications of the RFID system, tags are attached on the objects such as books or folders and the distance between each tag is extremely short. Therefore, the RFID tag is influenced by the attached objects and the other tags close to it. In this paper, a meander antenna which has good performance on high dielectric objects and closely located has been proposed. The simulation results show that deciding the input impedance of the tag antenna is important to tag design. The proposed tag antenna has higher power transmission ratio than the normal planar dipole antennac when the tags are located closely or attached on a dielectric. The conjugate matching between tag antenna and chip has been realized so that the resistance of the tag to other objects has been enhanced.

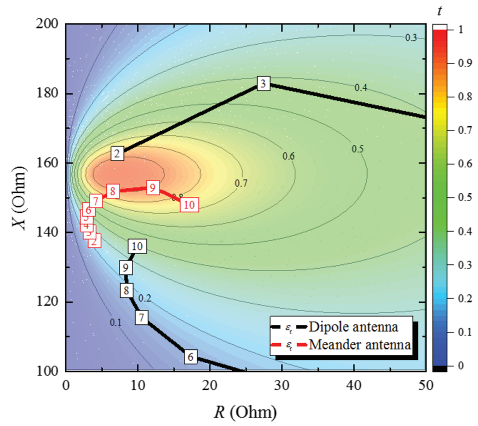

Figure 14: Power transmission ratio of one tag attached on dielectric with different ε_r.

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