Closely Located RFID Tag Antennas on High Dielectric Objects

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***Abstract* - Sensitivity of the tag of radio frequency identification (RFID) system is one of the most important factors to evaluate the tag performance. The sensitivity is usually degraded when the tags are located very closely or when they are attached on the surface of high dielectric objects because the power transmission ratio between chip and antenna of the tag is decreased due to the impedance mismatching. In this paper, the tag antenna is designed and studied for the tag which is applied to the closely located applications and the high dielectric constant objects. Numerical study shows that the tag can keep a high power transmission ratio when they are used in the closely located applications and the high dielectric constant objects.**

***Index Terms* — RFID, tag antenna, near-field, dielectric constant, impedance matching, small antenna.**

1. Introduction

In recent years, RFID is one of the most promising technologies for wireless identification system and sensor network system, such as retail store, security, electronic wallet, and so on [1]. The RFID systems are composed of reader devices and RFID tags which are attached on the objects for track inventory and assets [2]. However, there are two technical problems in this system. First, the reading performance of the system is not stable when the system is used for monitoring the objects which are thin and small such as books and documents in the library. In this case, the tag antennas are located closely and the mutual coupling between the tag antennas strongly give effects on the tags. Second, when the objects to be monitored has a high dielectric constant such as glasses and ceramics in the department store, the reading performance becomes also poor due to the electric characteristics of RFID tags are changed by the high dielectric objects. Therefore, it is required to design the RFID tags which can operate well when they are located very closely or attached on objects of a high dielectric constant.

In this paper, an UHF RFID tag antenna which has good resistance to the influence from other nearby objects is studied. The tag has a good performance when it is located closely with other tags or attached on the high dielectric objects. The tag antennas are studied numerically by using the method of moments, and the reading performance of RFID tags are numerically and experimentally evaluated to show the good performance of the tags in terms of power transmission ratio between the tag antenna and the chip in the tag.

2. Definition

A RFID tag consists of an antenna and a chip. It can be considered as an one-port network circuit [3] and the equivalent network circuit is shown in Fig. 1.

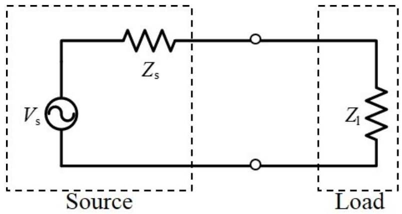

Fig. 1. Generator-load network circuit.

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.

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

$$\Gamma = \frac{Z_l - Z_s^*}{Z_l + Z_s} \quad (1)$$

and the power transmission ratio t can be written as

$$t = 1 - |\Gamma|^2, 0 \leq t \leq 1 \quad (2)$$

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 Evaluations

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(a), where l_a = 90 mm and w_a = 17 mm. It is designed to conjugate match to the RFID chip [4]. The impedance of the chip at 920 MHz with -13 dBm incident power is 7.2-j156.5 Ω. However, RFID tags

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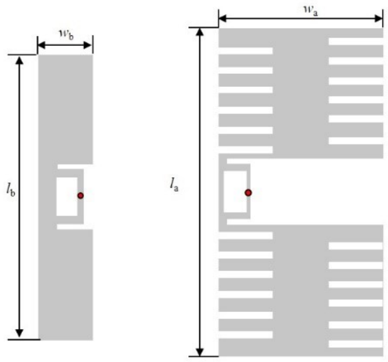
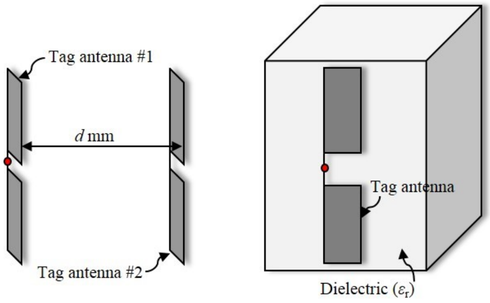
are influenced by nearby objects which can cause the change of the antenna impedance. The simulation model of two situations are shown in Fig. 3. Fig .3(a) illustrates that two tags close to each other and the distance between two tags is *d*. Fig .3(b) illustrates that the tag is attached on a dielectric with relative permittivity ε_r.



(a) (b)

Fig. 2. Two tags designed for UHF RFID system: (a) planar dipole antenna and (b) meander antenna.



(a) (b)

Fig. 3. Simulation model for (a) two tags close to each other and (b) one tag attached on dielectric.

In order to enhance the resistance of the tag antenna to other objects nearby, a meander dipole antenna which is using the same chip impedance as the pervious one as shown in Fig. 2(b) is proposed, where l_a = 100 mm and w_a = 50 mm. Two tags in each condition are analyzed by using method of moment and the simulation results are shown in Fig. 4 and Fig. 5. 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. 4 shows that the dipole antenna has high power transmission ratio to the chip when the tag is far from the other one, but the proposed meander antenna has high power transmission ratio when the tag is close to the other one. Fig. 5 shows that the dipole antenna attached on the dielectric has large variations in the impedance. On the other hand, the meander antenna has good resistance to the dielectric. It is demonstrated that the proposed meander antenna has high power transmission ratio when the tag is closed to the other one or the tag is attached on the dielectric.

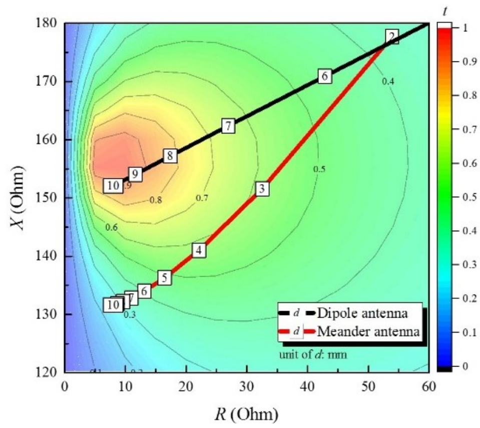


Fig. 4. Power transmission ratio of two tags close to each other with different *d*.

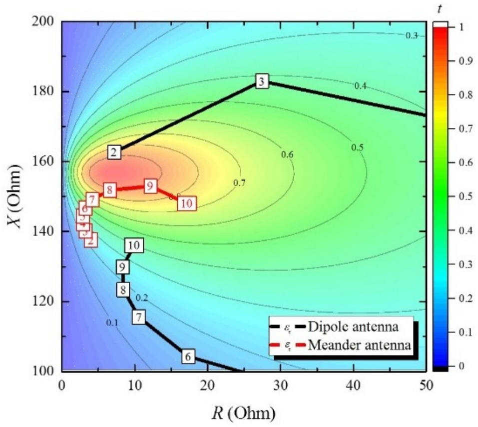


Fig. 5. Power transmission ratio of one tag attached on dielectric with different ε_r.

4. Conclusion

It was shown that it is important to match the input impedance of the tag antenna and the chip to achieve the maximum power transmission ratio.

The tag antenna which has large electrical size can usually keep a high power transmission when the tag is closely located and attached on an object with high dielectric constant. A meander antenna was proposed to reduce the physical size of the antenna without decreasing the power transmission ratio. The simulation results confirmed that the proposed meander antenna has a better performance than the normal dipole-type antennas.

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