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Development of a Passive RFID-Tag with 10-m Reading Distance under RCR STD-1 Specification

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1. Introduction

Recently, popularity of the RFID system as identification and tracking technology has been growing rapidly. The RFID system is composed of the base station (reader) and the transponder (tag). Since the RFID tag is required to be compact, low price and long life without any the maintenance, passive RFID tag without battery used at 2.45 GHz ISM band is most suitable. However, the distance between the reader and the tag is limited because the field strength of the responding signal from the tag is proportional to the inverse of the square of the distance and becomes weak as the distance increases. Therefore, it is important to develop an RFID tag applicable for a long reading range.

In this paper, a novel passive RFID tag for a 10 m reading range under RCR STD-1 specification [1] is proposed, where the transmitted RF power of the reader is 300 mW at the operating frequency of the 2.45 GHz ISM band and the actual gain of the reader antenna gain is 20 dBi. The proposed tag is composed of a divided microstrip antenna and a rectifying circuit boosting the DC voltage based on the Cockcroft-Walton [2] circuit, and the size is about 60×20×2 mm.

2. Geometry of tag antenna

Fig.1 shows the structure of the conventional passive RFID tag [3]. Variable impedance Z_v for the modulation of the transponding signal is connected to the feeding termina1 A-B of the tag antenna. A rectifying circuit for receiving the power is also connected in parallel to the terminal A-B. Fig. 2 shows the structure of the proposed passive RFID tag. The tag antenna is a divided microstrip antenna. PIN diodes as the variable impedance element for the modulation and a rectifying circuit are connected to the terminals A-B and B-C, respectively.

Fig. 3 shows the schematic diagram for evaluating the received signal level from the tag at the reader. The received signal level at the frequency of f_0+f_{LO} are calculated by using the method of moments (MoM), where f_0 is the RF frequency and f_{LO} is the local frequency of the modulation of the RFID tag. The modulation is performed by the PIN diode in the tag. Fig. 4 shows the received signal power normalized by the transmitted power of the reader antenna as a function of the length of the tag antenna L for the cases of the conventional RFID tag having planer dipole antenna without ground plane and the proposed tag with divided microstrip antenna. The actual gain of the reader antenna is assumed to be 20 dBi according to the STD-1 specification. The series resistance and the junction capacitance of the PIN diodes are supposed to be R_s=1 Ω and C_0=2 pF, respectively and the distance between the tag and the reader antennas is z=83λ (10 m). It is noted that the received power level of

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the proposed tag is about 10 dB higher than that of the conventional tag by selecting an appropriate antenna length.

Fig. 5 shows the received signal level of the proposed tag with varying the values of the series resistance R_s and the junction capacitance C_0 of the PIN diodes. The value of the junction capacitance does not affect the received signal level significantly, while the value of the series resistance strongly changes the received level, and a small series resistance is desirable to increase the distance between the reader and the tag.

3. Rectifying circuit

For the case of the rectifying circuit of the conventional tag shown in Fig. 1, a high impedance of the tag antenna is desirable to obtain the high DC voltage. However, required power to generate 1 V for the control circuit is more than 0 dBm even when a high impedance antenna such as the folded dipole antenna is used, because a simple diode rectifying circuit is used.

The received power of the microstrip antenna of the proposed tag is estimated to be about -10 dBm at the distance of z=10 m assuming that the transmitted power is 300 mW and the gain of the reader antenna is 20 dBi. This power is enough to operate the control circuit of the RFID tag. However, the estimated value of the received DC voltage is as low as 0.1 V assuming 50 Ω load, which is too small to operate the control circuit. Therefore, a rectifying circuit boosting DC voltage more than 10 times and working at 2.45 GHz band is required to obtain the DC voltage higher than 1 V with 30 μW power consumption.

Fig. 6 shows the proposed rectifying circuit composed of a tank circuit of a $\lambda/4$ short stub and modified 3-stage Cockcroft-Walton circuit. The first diode of the original Cockcroft-Walton circuit [2] is removed. The uniform values of the capacities in the original Cockcroft-Walton circuit are also changed as lower capacitance of the input side capacities. The rectifying diode used in this study is HSMS-286 (C_0=0.25 pF). DC output of the proposed rectifying circuit is numerically analyzed by using the SPICE transient simulator. Fig. 7 shows the frequency response of the proposed rectifying circuit when the input RF power is -10 dBm and load resistance is R_L=33 kΩ. DC voltage of about 1.15 V is obtained which is considered to be enough to operate the control circuit. The conversion efficiency of the proposed rectifying circuit is about 40%, which is much greater than the conventional Cockcroft-Walton circuit.

4. Conclusion

A novel passive RFID tag for a long reading range composed of a divided microstrip antenna and a rectifying circuit boosting the DC voltage has been proposed. It has been shown that the received level at the reader for the case of the proposed tag is about 10 dB greater than that for the case of the dipole antenna of the conventional tag. Since antenna is a microstrip type antenna having a ground plane, it can be used in the vicinity of a metal structure. The proposed rectifying circuit is composed of a tank circuit of a $\lambda/4$ short stub and modified 3-stage Cockcroft-Walton circuit and can convert from 0.07 Vrms RF voltages of 2.45 GHz to more than 1 V DC voltages which corresponds to the efficiency of about 40%.

References

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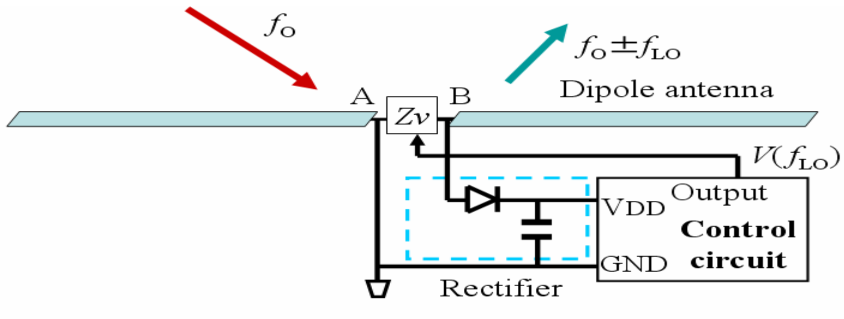

Fig.1 Structure of conventional passive RFID tag.

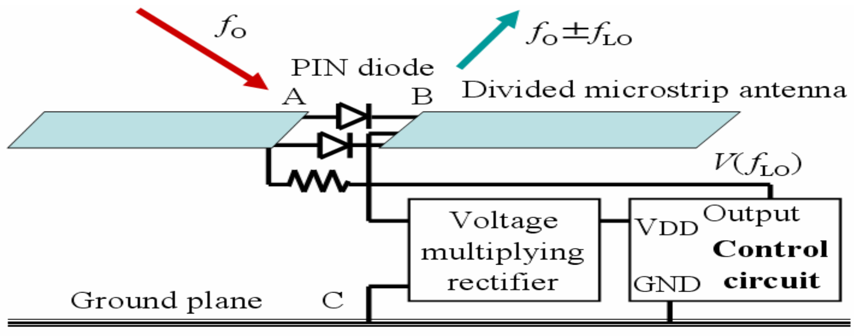

Fig.2 Structure of proposed passive RFID tag.

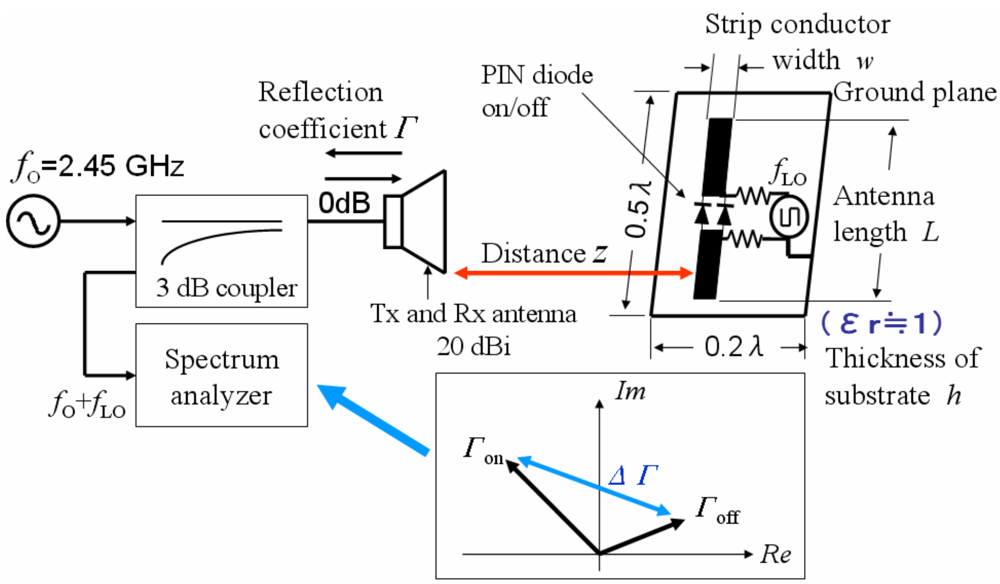

Fig.3 Schematic diagram for evaluating received signal level at reader.

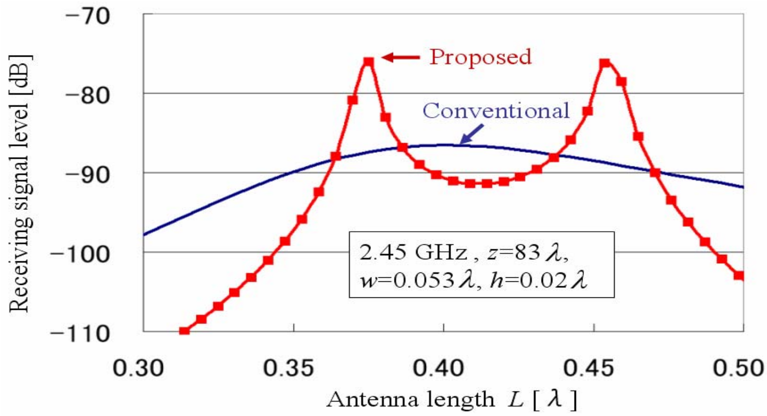

Fig.4 Received signal power normalized by transmitted power of reader antenna as a function of length of the tag antenna L.

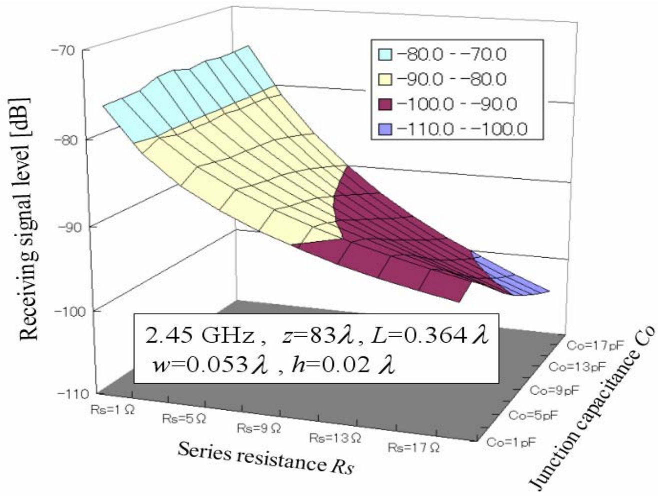

Fig.5 Received signal power normalized by transmitted power of reader antenna versus series resistance and junction capacitance of PIN diode.

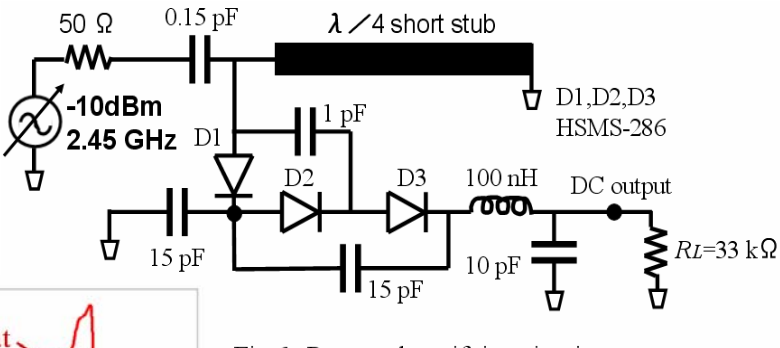

Fig.6 Proposed rectifying circuit.

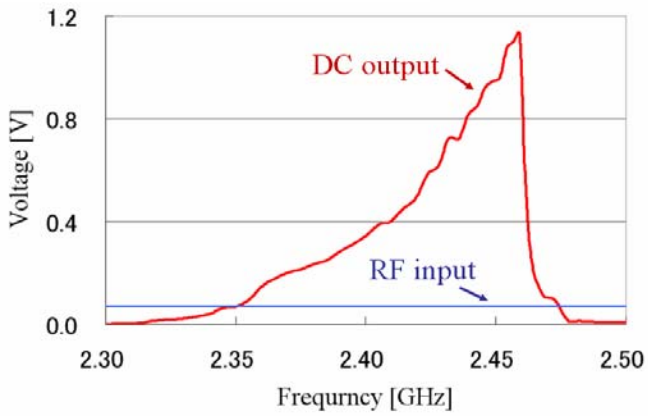

Fig.7 Frequency response of proposed rectifying circuit.