Long Range Passive RFID-Tag for Temperature Monitor System

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1. Introduction

RFID systems have been applied to many systems as the identification and tracking techniques. The RFID system is composed of a base station (reader) and a transponder (tag). Since the RFID tags are required to be compact, low price and long life without any maintenance, passive RFID tags without battery are desired. However, the distance between the reader and the tag has been less than 10 m because the field strength of the response signal from the tag is proportional to the inverse of the square of the distance and becomes weak as the distance increases. The longest ranges of RFID tags using conventional dipole antenna were 9.25 m at 915 MHz [1] and 3.3 m at 2.45 GHz [2]. Therefore, it is strongly desired to develop an RFID tag applicable for a long reading range to realize novel communication network systems. Recently, a passive RFID-Tag with a range of 10 m composed of a divided microstrip antenna and a passive voltage multiplying circuit has been proposed by the present authors for the Japanese RFID equipment specification at 2.45 GHz ISM band [3].

In this paper, passive RFID tags for a range longer than 20 m are proposed for 4W EIRP system at 950 MHz band [4] and the RCR STD-1 specification at 2.45 GHz ISM band [5]. Fabricated RFID tags have sizes of 90×60×4 mm and 60×25×4 mm for 900 MHz and 2.45 GHz bands, respectively, and are applied to monitor system of temperature.

2. Tag antenna and variable impedance element

Fig. 1 shows the structure of the proposed passive RFID tag. The tag antenna is a divided microstrip antenna. Two diodes are connected to the terminal A-B as the variable impedance element for the modulation and a rectifying circuit is connected at B-C. Since the microstrip type antenna having a ground plane is employed, it can be used in the vicinity of a metal structure.

The level of the response signal received by the reader antenna is numerically analyzed by MoM and circuit simulator. Fig. 2 shows the received signal level as a function of frequency with varying the values of series resistance of the diodes R_s attached to the divided microstrip antenna, where the junction capacitance of the diode is C_0=1 pF. The total length of the antenna is L=0.364 λ_0 and the distance between the reader and tag is 83 λ_0. It can be seen that the smaller series resistance is desired to obtain a strong response signal level.

Figs. 3 and 4 show the peak value of the received signal level as functions of the series resistance R_s and the junction capacitance of the diode C_0 for the cases of the conventional RFID tag using dipole type antenna and the proposed RFID tag. Since the frequency of the peak of the response level varies as the values of the series resistance R_s and the junction capacitance C_0 change, peak value of the

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received signal level was numerically sought with changing frequency and is plotted in these figures. In the conventional RFID tag, the junction capacitance C_0 strongly affects the received signal level, while the series resistance R_s does not. On the other hand, R_s strongly affects the received signal level, while the C_0 does not in the case of the proposed antenna as can be seen in Fig. 4.

3. System and experimental results

Fig. 5 shows a rectifying circuit used for a fabricated passive RFID tag at 2.45 GHz. Varactor diodes are employed as the variable reactance elements for the modulation, since varactor diode have a small series resistance R_s and a large junction capacitance C_0. By using the circuit shown in Fig. 5 and varactor diodes, a DC voltage of 0.6 V and a DC current of 2 μA are obtained to transmit the temperature data for the input RF power of -20 dBm of the rectifying circuit.

Figs. 6 and 7 show the fabricated passive RFID tags having temperature sensors for 2.45 GHz band and 860-950 MHz band, respectively. The actual gains of antennas used in these tags are about 5 dBi, and the received power transmitted by the readers 30 m away from the tag is -20dBm under the operations of the RCR STD-1 specification and 4 W EIRP systems.

Fig. 8 shows the measured DC voltage of the fabricated tag for 860-950 MHz band as a function of the career frequency, where transmitted power of the reader is 0.25 W EIRP and the distance between the reader and tag is z=3 m. Although the divided microstrip antenna and the quarter-wavelength short stub have narrow band characteristics, the overall rectifying characteristics have a broad band width greater than 10 % and the proposed RFID tag can be used for both Japanese system at 950 MHz and European system at 860 MHz.

Indoor experiment of the temperature monitor system using two passive tags for 2.45 GHz band was performed. Figs. 9 and 10 show the experimental setup. The transmitting and receiving antennas are both double-ridged guided horn antennas. The response signal received by the reader antenna is delivered to a spectrum analyzer. The transmitted power of the reader is 0.1 W and the value of the EIRP is 0.56 W which is only 2 % of the RCR STD-1 specification. Since the space for the experiment is limited, the distances between the tags and the reader are 3 m and 3.5 m for tags #1 and #2, respectively. These ranges are corresponding to 22 m and 26 m under the RCR STD-1 operation, respectively. Each tag converts the received career frequency into an individual sub-career frequency depending on the temperature and transmits it to the reader.

Fig. 11 shows the frequency deviation of the response signals received by the reader antenna. The combinations of the temperature of tags #1 and #2 were (27°C, 27°C), (44°C, 27°C) and (44°C, 53°C). It can be seen that the temperature can be monitored with a frequency deviation of approximately 1 Hz/°C confirming the validity of the passive RFID tags. In this system, temperature of -40°C to 85°C can be measured with an accuracy of 0.3°C.

4. Conclusion

Passive RFID tags for a range longer than 20 m have been proposed for 4W EIRP system at 950 MHz band [4] and the RCR STD-1 specification at 2.45 GHz ISM band [5]. It has been pointed out that the series resistance of diodes used for the modulation is important to increase the level of response signal. Experimental study of fabricated passive RFID tag using varactor diodes, which have small series resistance, shows that 30 m range response can be achieved at 860-950 MHz band. Passive tags for temperature monitor system at 2.45 GHz band have been also fabricated to demonstrate validity of proposed tags for a range longer than 20 m. The tags have sizes of 90×60×4 mm and 60×25×4 mm for 900 MHz and 2.45 GHz bands, respectively, and have been applied to monitor system of temperature.

References

[1] Udo Karthaus and Martin Fischer, “Fully Integrated Passive UHF RFID Transponder IC With 16.7-μW Minimum RF Input Power,” IEEE Journal of Solid-State Circuits, vol. 38, no. 10, pp.1602-1608, Oct. 2003.

[2] G. Scholl, C. Korden, E. Riha, C.C.W. Ruppel, U. Wolff, G. Riha, L. Reindl, R. Weigel, “SAW-Based Radio Sensor Systems,” IEEE Microwave Magazine, vol. 4, no. 4, pp. 68-76, Dec. 2003.

[3] Hitoshi Kitayoshi and Kunio Sawaya, “Development of a Passive RFID-Tag with 10-m Reading Distance under RCR STD-1 Specification,” Proceedings of ISAP’04, pp. 969-972, Sendai, Japan, Aug. 2004.

[4] Ministry of Internal Affairs and Communication, “MIC receives partial report from Information and Communications Council concerning technical conditions for high-power passive tag systems using the 950 MHz band,” http://www.soumu.go.jp/joho_tsusin/eng/Releases/Telecommunications/news041215_2.html, Dec. 2004.

[5] “RFID Equipment for Premises Radio Station, RCR STD-1 3rd Ed.,” ARIB, Jul. 2003.

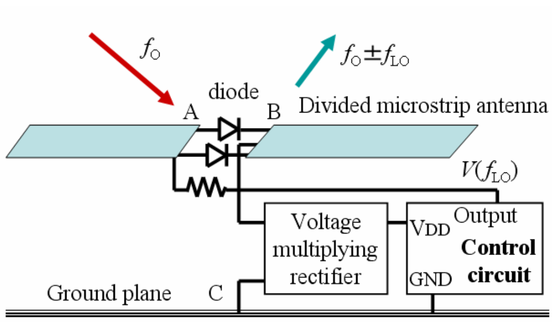

Fig. 1 Structure of proposed passive RFID tag.

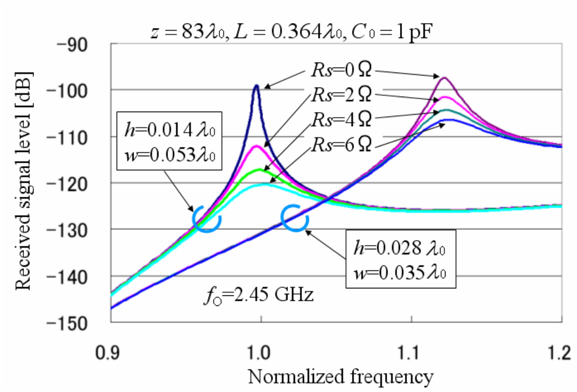

Fig. 2 Received signal level of reader antenna versus thickness h and strip width w in case of proposed RFID tag.

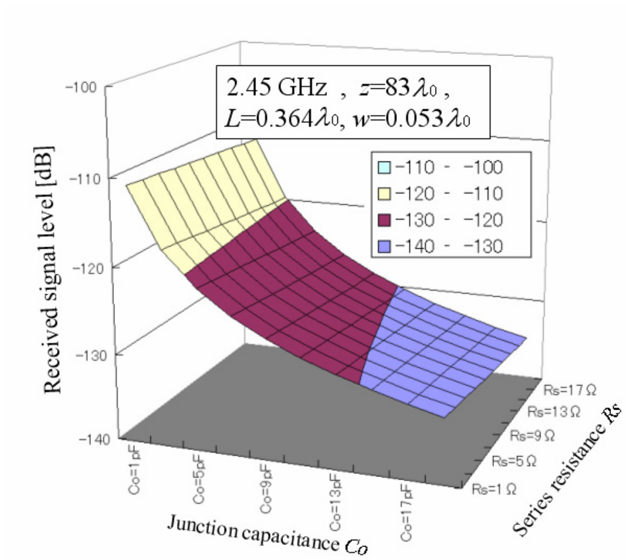

Fig. 3 Received signal level of reader antenna versus C_0 and R_s of PIN diode in case of conventional RFID tag.

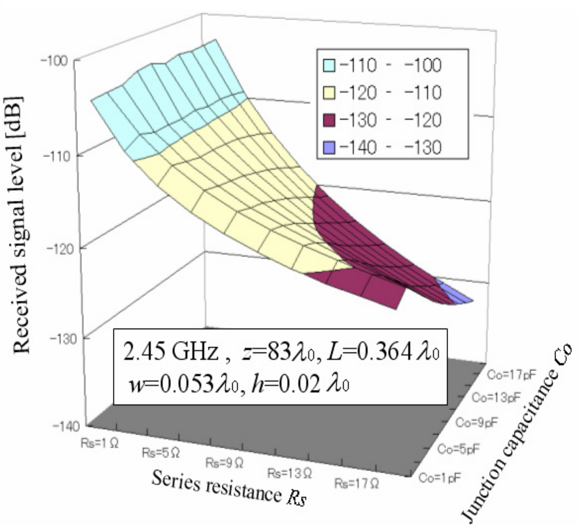

Fig. 4 Received signal level of reader antenna versus R_s and C_0 of PIN diode in case of proposed RFID tag.

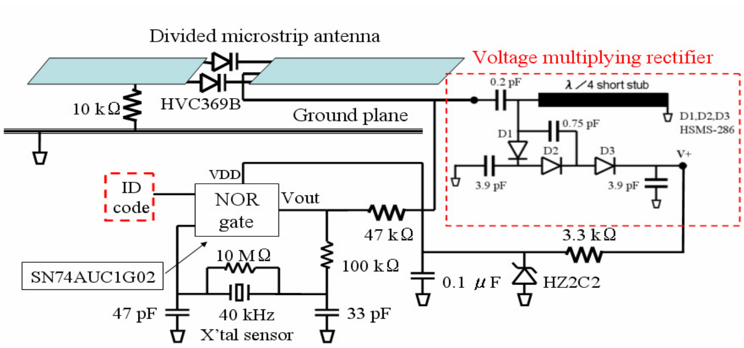

Fig. 5 Circuit diagram of temperature sensing passive RFID tag.

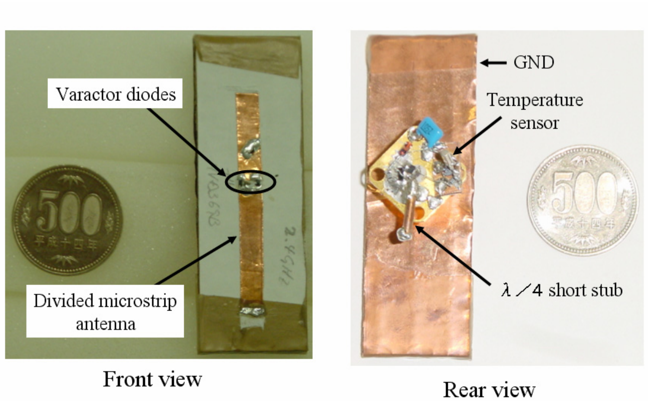

Fig. 6 Photograph of 2.45 GHz band passive RFID tag.

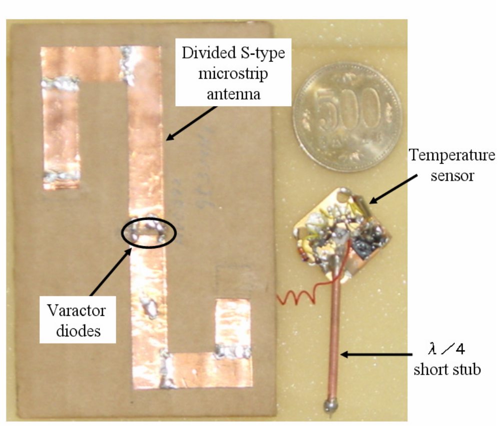

Fig. 7 Photograph of 860-950 MHz band passive RFID tag.

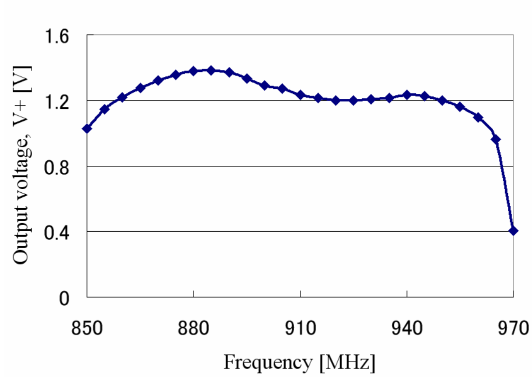

Fig. 8 DC power voltage of UHF band passive RFID tag as a function of the career frequency.

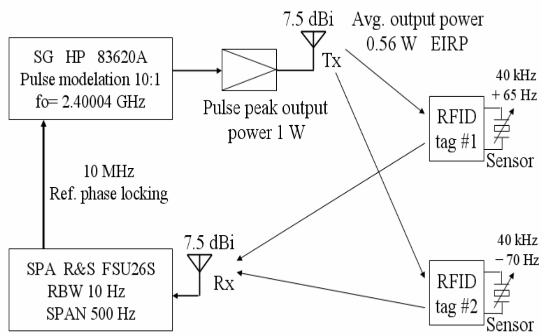

Fig. 9 Block diagram of experimental setup.

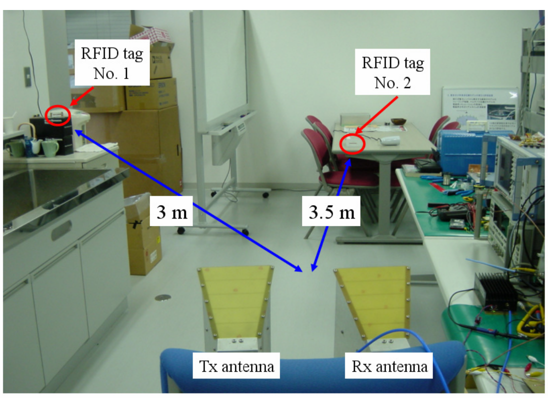

Fig.10 Photograph of experimental setup.

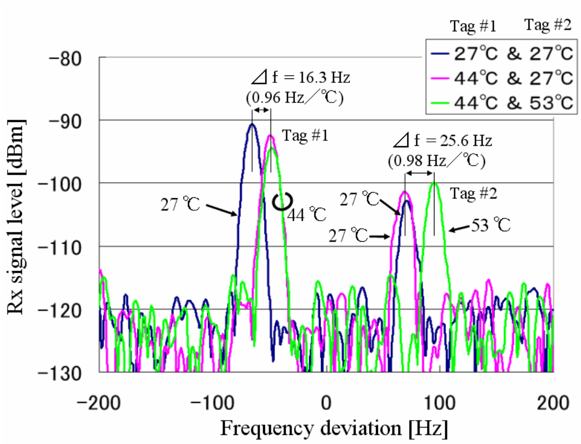

Fig.11 frequency spectrum of received signal from RFID tags at reader.