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Antennas for Ubiquitous Sensor Network

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Abstract

So far, the RFID applications are mainly developed in the public and industrial systems such as distribution, transportation and asset management. In recent years, a smart sensor node for RFID sensing system has also attracted considerable attention, and expected as one of important elements in order to realize wireless ubiquitous environments, for the expected applications such as monitoring of physical parameters, automatic product tamper detection, and so on. For a compact and smart sensor node, antenna system is required to be functional and intelligent. Thus two types of antennas, antenna with relative humidity sensing function and pattern reconfigurable antenna, are presented in this paper. Antenna with sensing function provides the compactness and function without additional sensor components. Using the modified polyimide synthesis, it has a dependent operating frequency on the humidity level with -181 kHz/%RH under 30%RH ~ 90%RH. Pattern reconfigurable antenna proposed for smart sensor nodes provides a function to radiate in omni-direction and end-fire direction to communicate with other nodes or readers as a user wants. These antennas are viable for use as one of important elements in compact and smart sensor node to realize ubiquitous environments.

1. Introduction

Radio frequency identification (RFID) sensing has attracted considerable attention in recent years. It is also expected to be an important element in the realisation of ubiquitous environments, especially in applications such as the monitoring of physical parameters, automatic product tamper detection, harmful agent detection, and non-invasive monitoring [1, 2]. RFID mechanisms can also be applied to collecting sensed data. Figure 1 shows the configurations of the RFID sensing system.

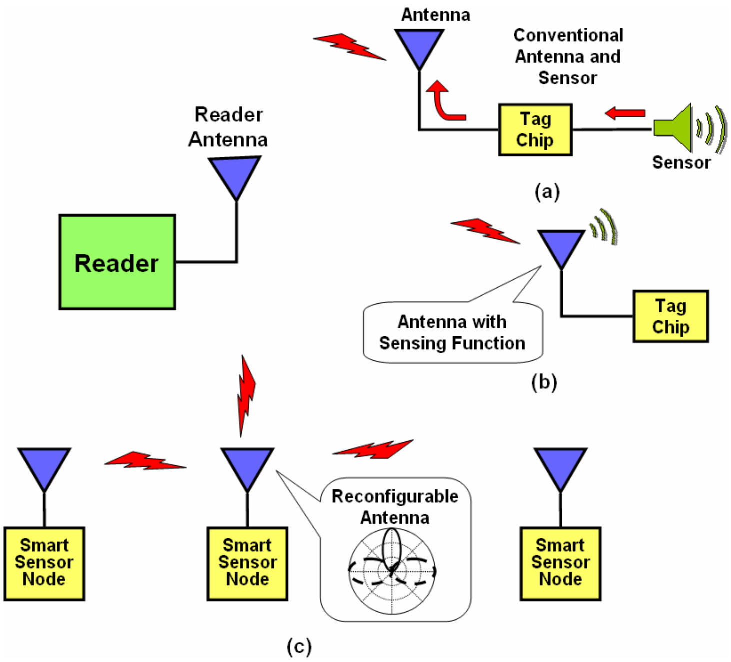

Figure 1 Configurations of the RFID sensing system: (a) Conventional antenna and sensor (b) Antenna with sensing function (c) Reconfigurable antenna with radiation pattern diversity

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For the monitoring of environmental conditions, as shown in Fig. 1(a), RFID tags with sensors are required so that the tags can send sensor-derived data to readers, though the addition of a sensor component increases the tag size and cost. However, as shown in Fig. 1(b), the physical and functional integration of the antenna and the sensor component provides compactness and cost-efficiency for a sensor tag. It shows the functional antenna plays a radiating role and a sensing role as well. Fig. 1(c) shows the configuration of smart sensor nodes using a reconfigurable antenna, which can provide radiation pattern diversity function. By controlling the current path with switches, it can operate as two entirely different antennas with different radiation patterns at the same frequency band. Using these antennas schemes, intelligent and functional sensor node can be organized. We now discuss the realisations of the proposed components, and the performances as well.

2. Sensing-Functional Antenna for Ubiquitous Environment

Figure 2 shows the configuration of the proposed functional antenna. The antenna consists of a resonant patch, a quarter wavelength transformer for matching, a 50 Ω feeding line, and modified polyimide film on the patch for sensing a relative humidity (RH). For being sensitive to moisture absorption, we synthesised a polyimide film from aromatic monomers where no hydrophobic element is included to have variable permittivity [3]. The synthesised polyimide material has increasing permittivity by moisture diffusion. As a sensor, a microwave resonator covered with this polyimide film has a dependent effective dielectric constant on humidity level. Since the resonant frequency relies on the effective dielectric constant, thus we can know the moisture level from the resonant frequency, as following Eq. (1). In addition, the narrowing of the frequency bandwidth of the resonator makes it easier to find the sensed values with a better resolution.

$$f_r \cong \frac{c}{2L\sqrt{\varepsilon_{eff}}} \tag{1}$$

where, f_r is fundamental resonant frequency; c is speed of light; L is the length of the patch antenna; ε_{eff} is the effective permittivity.

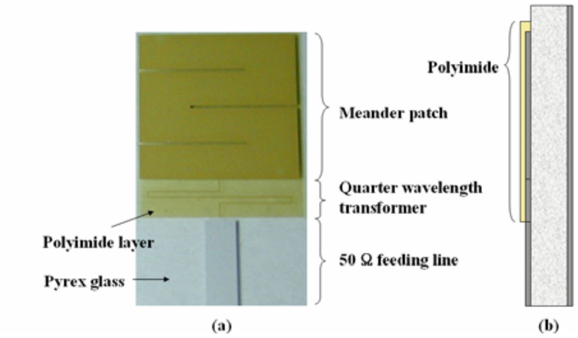
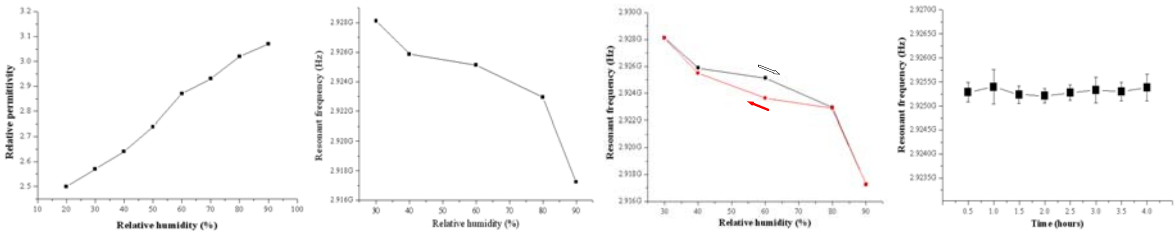


Figure 2 Configurations of the proposed antenna with RH sensing function:
(a) Top view of a photograph (b) Side view of the structure



(a) (b) (c) (d)

Figure 3 Characteristics of the synthesized polyimide film and the proposed antenna with the RH sensing function: (a) Measured relative permittivity of the synthesized polyimide film (b) Sensitivity in terms of resonant frequency (c) Hysteresis (d) Stability

To produce a modified polyimide-based appliance with good sensitivity, we used a microstrip patch antenna as a microwave resonator. Because the microstrip structure has a narrow bandwidth, the patch antenna can serve as a high-resolution sensor application. Furthermore, to enhance sensitivity, we ensured the patch antenna was meandered. A meandering patch adds a large reactance to the input impedance and the bandwidth of the antenna becomes narrower, thereby improving the sensitivity of the sensing function.

The relative permittivity increases from 2.5 to 3.1 with the ratio of about 0.008/%RH as a RH level varies from 20% to 90%, as measured relative permittivity of the synthesized polyimide film shown in Fig. 3(a). From the measured result in Fig. 3(b), sensitivity is -181 kHz/%RH under the condition of the 30%RH to 90%RH with the dynamic ranges from 2917 MHz to 2928 MHz. That is, moist diffusion into the polyimide film changes effective permittivity of the resonator. Hysteresis is 0.0013% (Fig. 3(b)), and percent deviation from an average resonant frequency is 0.002% at 40%RH (Fig. 3(c)).

3. Reconfigurable Antenna with Radiation Pattern Diversity for USN

Fig. 4 shows the basic concept of the reconfigurable antenna for radiation pattern diversity. It is a combination of a monopole antenna with an omni-directional radiation pattern and the quasi-Yagi dipole antenna with an end-fire radiation pattern with three switches. The antenna can be operated as either of the antenna by controlling the current paths. When all switches are 'on' state, the antenna can work as a quasi-Yagi dipole antenna, and when all switches are 'off' mode, the antenna can be operated as a monopole antenna. The chip capacitor and chip inductor are inserted to realize the RF/DC isolation, as the geometry of the proposed structure with the bias line shown in Fig. 5(a). Theoretically, the distance (*l1*) between ground plane and the dipole arm is about quarter-wavelength at the operating frequency f_c for the ground plane to be operated as a reflector at the quasi-Yagi dipole antenna, and for the monopole antenna to resonate. The length of the antipodal printed dipole is about half-wavelength. So to make the both antenna have the same f_c, the length *l1* and *l2* should be almost same. When it operates as a monopole antenna, the coupling effect between the dipole arm and monopole could occur by distance *d* between them, and the f_c could be slightly changed. Also, for a quasi-Yagi dipole antenna, the length *l1* affects the impedance matching of the antenna. Therefore, when designing the antenna, the distance *d* and the length *l1, l2* should be tuned.

A pin diode (DSG6405-000, Alpha industries) is used as a switch. When the bias is null, the diode exhibits as a capacitance of 0.02 pF, which can be regarded as an open load at 2.4 GHz. And when a forward bias (~1V) is applied to a diode, it acts as a resistor with 2 Ω. Fig. 5(b) shows the picture of the fabricated antenna. Fig. 5(c) shows the return losses of the antenna designed for the 2.4 GHz frequency band. When the diodes are at bias states, the bandwidth changed due to the fabrication errors yet to be ascertained. Fig. 6 shows the radiation patterns of the antenna at 2.45 GHz. It is found that the proposed structure provides a function to radiate in omni-direction and end-fire direction as the operating modes by switching. The prototype monopole and quasi-Yagi dipole antennas are used to measure the radiation pattern.

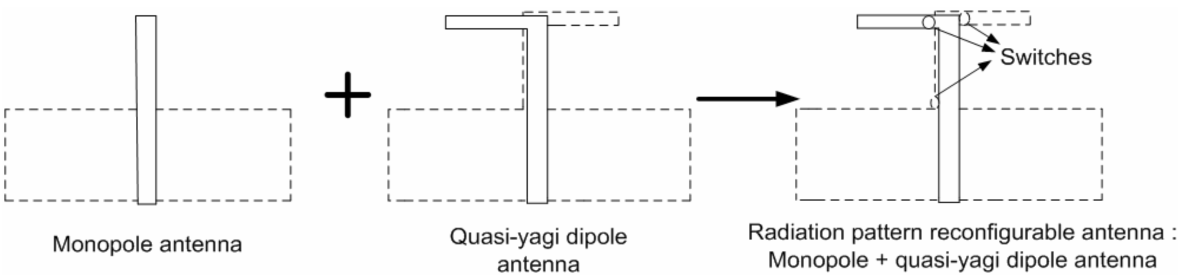
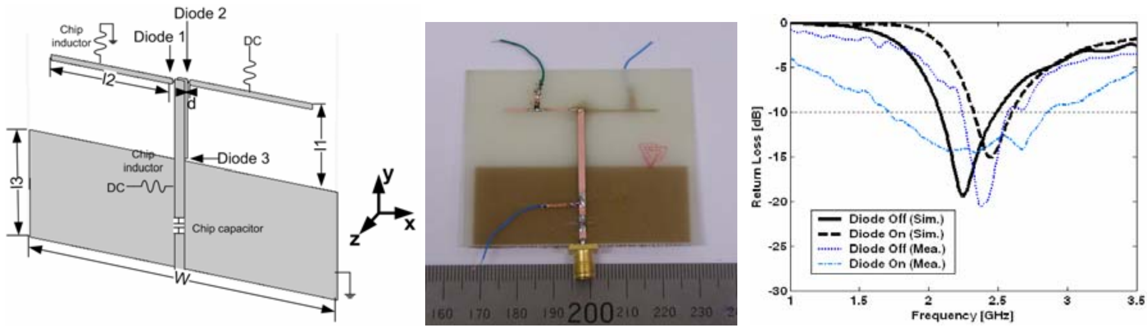
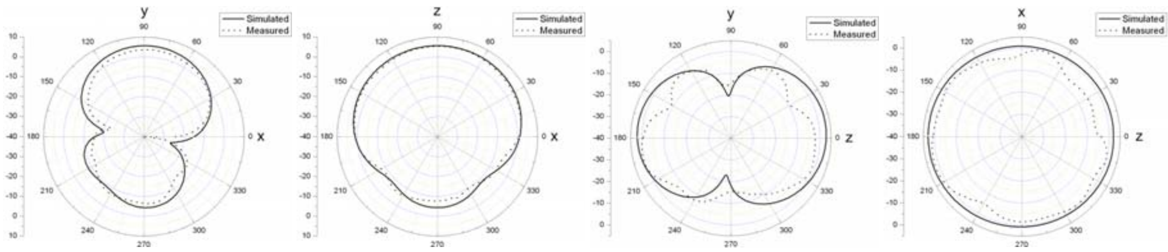


Figure 4 Basic concept of the proposed reconfigurable antenna



(a) (b) (c)

Figure 5 The reconfigurable antenna with radiation pattern diversity:
(a) Geometry (b) Photograph (c) Simulated and measured return losses



(a) (b) (c) (d)

Figure 6 Radiation patterns: (a) E-plane (quasi-Yagi dipole mode) (b) H-plane (quasi-Yagi dipole mode) (c) E-plane (monopole mode) (d) H-plane (monopole mode)

4. Conclusion

Antennas for ubiquitous sensor network environment have been proposed. The patch antenna integrated with the RH sensor using a modified polyimide film can be applied for a passive RFID sensor tag as a physically and functionally combined antenna with the RH sensor. The reconfigurable antenna proposed for smart sensor nodes provides radiation pattern diversity to intelligently communication with other nodes or readers as a user wants. Although these have insufficient problems to apply now to the commercial application, such as compatibility with other systems, fabrication tolerance, reliability, and so on, they could be much improved in the future research. The proposed antennas can be applicable as one of significant elements for the implementation of the ubiquitous sensor network.

Acknowledgments

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References

[1] K. V. Seshagiri Rao, Pavel V. Nikitin, and Sander F. Lam, "Antenna design for UHF RFID tags: a review and a practical application," *IEEE Trans. on Antennas and Propagation*, Vol. 53, No. 12, Pages 3870-3876, Dec. 2005

[2] Roy Want, "Enabling Ubiquitous Sensing with RFID," *Computer*, Vol. 37, No. 4, Pages 84-86, Apr. 2004

[3] Kihun Chang, Yong-Ho Kim, Yong-Jun Kim, and Young Joong Yoon, "Functional antenna integrated with relative humidity sensor using synthesised polyimide for passive RFID sensing," *Electronics Letters*, Vol. 43, No. 5, pp. 259-260, Mar. 2007