JSIIAF

RFWM: Wheat Moisture Detection Based On RFID
Shifeng Li Pengming Hu Weidong Yang
College of Information Science and Technology
Henan University of Technology

二等奖

Abstract

In this paper, we design a wheat moisture detection system RFWM based on RFID. The system realizes the sensing ability of wheat moisture using RFID tags radio frequency signal. According to the change of dielectric constant of different moisture content of wheat, the phase change of RFID tag RF signal will be caused to carry out wheat moisture sensing. The system uses path integral method to restore the real phase change of RFID tag signal in different moisture content of wheat, and then deduces the change of dielectric constant of wheat under different moisture content by using RFID real phase through electromagnetic wave propagation principle. Finally, the moisture content of wheat was obtained by fitting the dielectric constant. The experimental results show that our RFID system can achieve high accuracy in wheat moisture measurement using only one RFID tag and one antenna.

Proposed Method

1. Frame

RFWM is a wheat moisture detection system based on RFID. As shown in Figure 1, the system has four modules, including data acquisition module, phase unwrapping module, dielectric constant calculation module and moisture identification module. The system only uses a reader with an antenna and an RFID tag to complete the wheat moisture detection.

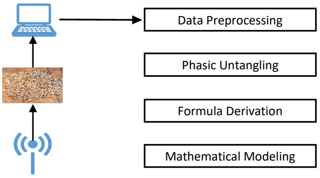

Figure 1. **System Framework Diagram**

2. Implementation Process

The propagation range of RFID belongs to the electromagnetic wave range. Therefore, based on the electromagnetic wave theory, we derive the formula for calculating the dielectric constant by using RFID phase value in the propagation range of RFID。The process is as follows:

Firstly, according to Maxwell's electromagnetic wave theory, the propagation velocity of electromagnetic wave in medium is as follows:

$$v = \frac{c}{\sqrt{\varepsilon\mu}} \qquad (1)$$

Where is μ the relative permeability of the medium, ε is the dielectric constant of the medium, and is the velocity of electromagnetic wave in the air, which is the octave of 3 * 10. Here we define the medium as wheat medium. From the above formula, the product of dielectric constant ε and permeability μ of wheat medium is:

$$\varepsilon\mu = \left(\frac{c}{v}\right)^2 \qquad (2)$$

At the same time, when the propagation distance and frequency are constant, the phase and wavelength of the target will change during the RF signal propagation. When the propagation of electromagnetic wave changes from air to wheat, At the same frequency f, the relationship between the propagation velocity c and the wavelength λ of electromagnetic wave in air and that of electromagnetic wave in wheat medium v and λ_0 can be expressed as.

$$f = \frac{c}{\lambda} = \frac{v}{\lambda_0} \qquad (3)$$

Where λ is the wavelength of electromagnetic wave in the air, λ_0 is the electromagnetic wave length in wheat medium. Combining (3) and (2), we can get :

$$\varepsilon\mu = \left(\frac{\lambda}{\lambda_0}\right)^2 \qquad (4)$$

However, we know that the permeability of the medium is one of the factors that affect the propagation of electromagnetic waves. Because grain is a non-magnetic medium, its relative permeability is approximately 1.Therefore, $\varepsilon\mu$ can be regarded as , so that the dielectric constant can be expressed as:

$$\varepsilon = \left(\frac{\lambda}{\lambda_0}\right)^2 \qquad (5)$$

It can be seen from the above formula that if we want to calculate the dielectric constant of wheat, we only need to calculate the wavelength of electromagnetic wave in the air and that in wheat medium, The wavelength λ in the air can be calculated from the velocity c and f the frequency of RF signal in the formula 3, and then only λ_0 is needed. For λ_0, we find that λ_0 can be obtained by measuring the true phase ϕ_0 of wheat medium in RFID communication system. In the previous section, we calculated the real phase of wheat medium measured by RFID through path integral method. It can be expressed as:

$$\phi_0 = \frac{4\pi d}{\lambda_0} + C \qquad (6)$$

Among them, d is the thickness of wheat medium, C is the inherent system noise generated in the transmission process of RFID system, but we cannot directly eliminate it. But the phase difference before and after the emergence of wheat can be measured by RFID system to eliminate C.

In the experiment, we can fix the tag and antenna, remove the wheat medium and measure the air phase. In the experiment, we can fix the tag and antenna, remove the wheat, and measure the air phase ϕ_{air} :

$$\phi_{air} = \frac{4\pi d}{\lambda} + C \qquad (7)$$

Where the wavelength λ in the air in the formula has been calculated by 3, next, the phase difference of the phase change before and after the appearance of the wheat medium is obtained as follows:

$$\phi_{0\text{-}air} = \phi_0 - \phi_{air} = \frac{4\pi d}{\lambda_0} - \frac{4\pi d}{\lambda} \qquad (8)$$

Among them, ϕ_0 , ϕ_{air}, λ and d are all known. From the above formula, λ_0 can be obtained. Then, λ_0 into 5 to calculate the dielectric constant ε of wheat medium. Next, the dielectric constant ε can be used as the characteristic of wheat moisture change.

Experiment

1. Data Presentation

As shown in Figure 2, the same batch of wheat was proportionally watered for different moisture content configurations, and all samples were kept sealed in a constant temperature cold storage for one to three months. After full absorption of moisture, the samples were taken out and calibrated with the national standard method to determine the true moisture. The different wheat samples were then placed in the experimental box for data collection, as shown in Figure 3.

Figure 2. **Wheat Sample Preparation**

Figure 3. **Data Acquisition Scenarios**

2. Experimental Results

We do experiment in the research laboratory to test the effectiveness of our RFWM system. Fig. 4 shows the accuracy of RFWM system for wheat with different moisture content. It can be seen from the figure that with the increase in wheat moisture content from 10.3% to 16.5%, the detection accuracy is also improved from 94% to 97%. In addition, the detection accuracy of each wheat water level reached 94%. The proposed RFWM system can achieve high accuracy in different wheat moisture content detection.

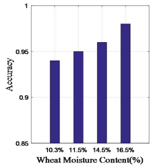

Figure 4. **Moisture Measurement Accuracy**

Conclusions

This paper introduces a wheat moisture detection system RFWM based on RFID. The feasibility of wheat moisture detection using dielectric constant data was demonstrated. The design of RFWM system was given, including data acquisition module, phase unwrapping module, dielectric constant calculation module and moisture identification module. Our experimental study shows the effectiveness of the proposed RFWM system, which can obtain high accuracy for the moisture detection of wheat samples with different water content.

References

[1] D. Vasisht, et al., “FarmBeats: An IoT platform for data-driven agriculture,” in Proc. USENIX NSDI’17), Boston, MA, Mar. 2017, pp. 515–529.
[2] Qian Zhang, Run Zhao, Dong Li, Dong Wang. Unobtrusive and robust human identification using COTS RFID[J]. Computer Network, 2020, 166.
[3] W. Yang, X. Wang, A. Song, and S. Mao, “Wi-Wheat: Contact-free wheat moisture detection using commodity WiFi,” in Proc. IEEE ICC 2018, Kansas City, MO, May 2018, pp. 1–6.
[4] W. Yang, X. Wang, S. Cao, H. Wang, and S. Mao, “Multi-class wheat moisture detection with 5GHz Wi-Fi: A deep LSTM approach,” in Proc. ICCCN 2018, Hangzhou, China, July/Aug. 2018, pp. 1–9.

联系方式

Contact Person：Shifeng Li
Mobile Phones：17839934504
Email：1006061024@qq.com