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# Design and Compared of Two Types of Microwave Moisture Instruments

**Xibin Bu[1], Zelun Li[2*]**
[1]Department of Information Engineering, Chuzhou Vocational Technology College, Chuzhou, China
[2]College of Mechanical and Dynamic Engineering, Chongqing University of Science and Technology, Chongqing, China
*****Corresponding author, e-mail: instru@163.com

***Abstract***

*In this paper, two types of microwave moisture measurement instruments were designed and compared with microwave dryness method and attenuation method separately. Compared with traditional moisture measurement instruments, the moisture instrument with microwave dryness method can detected the moisture content rapidly with high precision. On the other hand, the moisture instrument with microwave attenuation method can detect the moisture content with much higher speed but low precision, which can be used in the online measurement system.*

***Keywords****: moisture content，microwave dryness，microwave attenuation*



## 1. Introduction

In many industry fields, the moisture measurement of materials is the basis of machining process and technical parameters, and it is also an important means of controlling productive quantity [1-3]. Traditional moisture measurement instruments based on resistance models or capacitance models have been developed and applied in many fields [4-6]. But in some special fields, the moisture content should be measured rapidly with high precision [7, 8], and the instruments should be miniaturized, stable and long time continuous used [9-12]. So we designed two types of moisture measurement instruments with microwave dryness method and attenuation method separately.

## 2. Theories

The moisture measurement instrument with microwave dryness method adopts classic method of the moisture detection, and it also takes the advantage of microwave heating. With the heat of microwave, the moisture content of materials will evaporate rapidly, and the moisture ratio of materials can be obtained.

$$k = \frac{m_0 - m_1}{m_0} \times 100\% \tag{1}$$

Where $m_0$ and $m_1$ is the weight of materials before and after microwave heating respectively.

According to the characteristic of dielectric loss of materials, the absorbed microwave power of materials can be shown as follow:

$$P = 2\pi\varepsilon_0\varepsilon_r fE^2 \tan\delta \tag{2}$$

Where $\varepsilon_0$ is dielectric constant of vacuum, $\varepsilon_r$ is dielectric constant of materials, $f$ is frequency of electric field, $E$ is intensity of electric field, and $\tan\delta$ is tangent of loss angle.

Expression (2) shows that the heat energy produced by microwave lies on frequency, intensity of electric field, dielectric constant of materials and tangent of loss angle. Microwave

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heats fast because electric field and work frequency are very high. In addition, microwave heating is selective, and the dielectric constant of water is 75.84, which is much bigger than others, so water can absorb microwave energy intensively [13-15]. Besides, microwave has the ability of penetrability and its penetrable depth D is approximately as follow:

$$D = \frac{0.318\lambda}{\sqrt{\varepsilon_r}\tan\delta} \quad (3)$$

Where $\lambda$ is the wavelength of microwave.

The moisture measurement instrument with microwave attenuation method can detect the moisture content through measuring the variety of the dielectric constant of materials, and the dielectric constant of materials is changed because of different moisture content [16-18]. The electric field of microwave can be expressed as:

$$E = A\sin(\omega t - \varphi) \quad (4)$$

Where A is the amplitude, $\omega$ is the angular frequency and $\varphi$ is the phase of the microwave.

The amplitude of microwave attenuation can be expressed as:

$$A = 8.686\frac{L\pi}{\lambda}\sqrt{\frac{\varepsilon_1 - p}{2}[1 + (\frac{\varepsilon_2}{\varepsilon_1 - p})^2 - 1]} \quad (5)$$

In the same way, the phase of microwave can be expressed as:

$$\varphi = \frac{2\pi L}{\lambda}\sqrt{\frac{\varepsilon_1 - p}{2}[1 + (\frac{\varepsilon_2}{\varepsilon_1 - p})^2 + 1]} \quad (6)$$

Where $\varepsilon_1$ and $\varepsilon_2$ is the dielectric constant of materials, which is various because of different moisture content of materials. So the moisture content can be measured through detecting the amplitude and the phase of microwave.

## 3. Experiments

### 3.1. Design of the Moisture Instrument with Microwave Dryness Method

With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely. In the meantime, piracy becomes increasingly r. Although encryption can provide multimedia content once a piece of digital content is decrypted, the dishonest customer can redistribute it arbitrarily There are five parts in the general design of the moisture instrument with microwave dryness method, including system of power supply, microwave magnetron, microwave heater, weight sensor system and SCM controlling system, as shown in Figure 1.

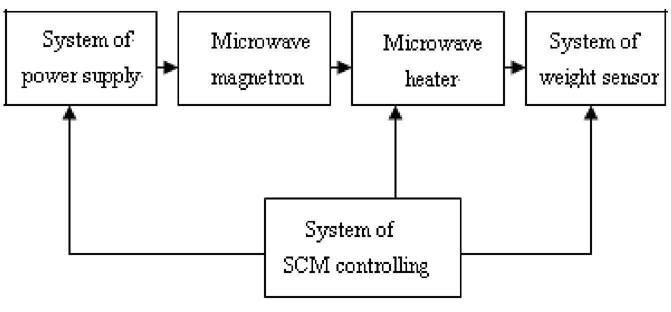


Figure 1. System of Moisture Instrument with Microwave Dryness Method

The microwave heater of moisture instrument is also named microwave drying apparatus, and it is an interaction effect space of microwave electromagnetic field materials, and it is also a working area where materials absorbs microwave energy. We choose box type of microwave heater for the moisture instrument. The box type of microwave heater is a multi-model cavity. Given proper size, it can make electromagnetic field symmetrical with very low power density.

There are three criterions in our design. First, the heating must be symmetrical. Second, the efficiency of microwave must be high. The last is the leakage of microwave must be as little as possible.

Suppose the lengths of the sides of the rectangle cavity are a, b and c respectively, and m, n and p in the equation (7) are the signs of the models, and $\upsilon$ is the velocity of light, and the central working frequency $f$ is 2450MHz here, resonance frequency $f$ of the cavity and its wavelength $\lambda$ can be expressed as follows:

$$f = \frac{\upsilon}{2}\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{c})^2} \tag{7}$$

$$\lambda = \frac{2}{\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{c})^2}} \tag{8}$$

The frequency of the microwave magnetron will be influenced by the changes of the load, there is $\Delta f = \pm 3MHz$ for the central working frequency $f_0$ of the microwave magnetron, so expression (7) can be changed into expression (9).

$$f_0 - \Delta f \le \frac{\upsilon}{2}\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{c})^2} \le f_0 + \Delta f \tag{9}$$

With the units of $f$ in KMz and unite sides of side-lengths in cm, (7) and (9) can be expressed in (10) and (11).

$$f = 15\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{c})^2} \tag{10}$$

$$2.42 \le 15\sqrt{(\frac{m}{a})^2 + (\frac{n}{b})^2 + (\frac{p}{c})^2} \le 2.48 \tag{11}$$

According to hereinbefore thoughts, we can give randomly the lengths of three sides of the resonating cavity and obtain the mode parameters m, n and p and its resonance frequency. We set different lengths of the sides a, b and c to test the model, considering the hardware condition of the laboratory, at last we choose 31cm, 31cm, 31cm as the lengths of three sides.

We select GZL OP07 as weight sensor for the moisture instrument, meanwhile, INA114 and AD654 is choosed as the interface circuits of the weight sensor. We make out a conditioning circuit and do a lot of experiments. The most difficult problem in the experiments is how to resolve stability and temperature drift in long-term tests. According to the experiments, the main factor which influences the stability of the microwave moisture instrument is the temperature changes of its crust in the range of 15℃ nearly, so the compensations of hardware and software are adopted to resolve its stability and the temperature shift.

AT89C52 is selected as the center of data collection and controlling, including input and output interface assistant circuit, and the SCM system hardware of moisture instrument is shown in Figure 2.

The system circuit diagram is drawn by Protel99 and debugged through the software simulation, then the circuit board will be processed, and the parts of the apparatus must be filtrated through aging handling.

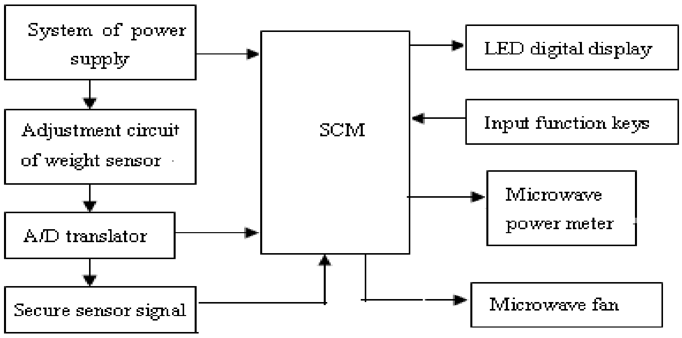


Figure 2. SCM System Hardware

There are three main functions of the SCM controlling system software of the moisture instrument. The first is to tare, and the second is to weigh the materials which are peeled off automatically, and the last is to measure and calculate the moisture ratio of materials. The foregoing two functions carry out the function of electronic balance.

The idea of the design includes the frame of the main procedure and the constitutions of the subprograms. There are seventeen subprograms including interrupt service subprograms in order to make the software clear, high efficient and continuous when it works.

### 3.2. Design of the Moisture Instrument with Microwave Dryness Method

The structure of the moisture measurement instrument with microwave attenuation method is shown in Figure 3. The microwave which is produced by the microwave source can be transmitted through the isolator and the adjustable attenuator, when it reaches the materials box, it will be absorbed by materials and the energy of the microwave will be decreased. The microwave is transmitted through the receiving antenna, the detector, the signal amplifier and AD converter, and then the attenuation can be detected by AT89C51. The relationship between the microwave attenuation and the moisture content is shown in Figure 4.

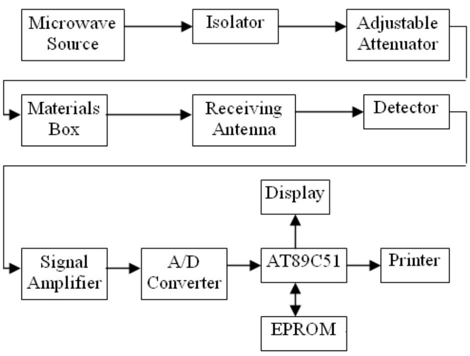


Figure 3. Structure of the Moisture Instrument with Microwave Attenuation Method

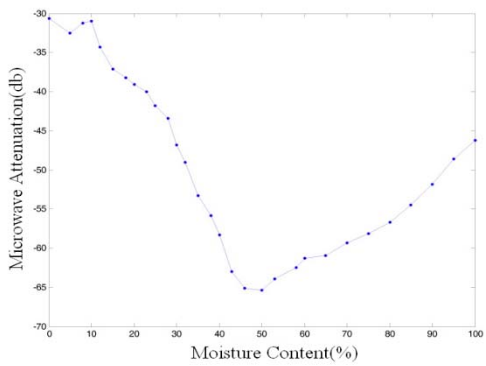


Figure 4. Relationship between Microwave Attenuation and Moisture Content

## 4. Conclusion

Two types of moisture measurement instruments were designed separately with microwave dryness method and attenuation method. The principles of the moisture instruments were analyzed theoretically, and the systems of two instruments were designed and compared. The results show that the moisture instrument with microwave dryness method has the characteristics of high precision and high speed, and the moisture instrument with microwave attenuation method can be used in the online measurement system with much higher speed but low precision.

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