

Paddy Moisture Content Determination with Reflection Measurement

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Abstract The paddy moisture content (Thai Hom Mali rice) was expressed as the magnitude and phase ratio relationship of the reflection coefficient (R) measured at 2.4 GHz. The experiment found that the relationship between R ratio and paddy moisture is a linear equation with the relationship between variables $R^2 = 0.958$ at 25°C. The experimental results showed that the moisture content was in the range of 16.3%-28.6%. The calibration equation between the experiment and the measurement showed that at the moisture level of 18.4%-20.5%, the obtained moisture content had an error of 0.15%-1.14%. This moisture content determination does not take into account changes in temperature and thickness of the paddy layer.

Keyword Thai Hom mali rice, Moisture measurement, Reflected wave, Linear equation

1. INTRODUCTION

Rice is an important food for Thai people and Thailand is a top international rice exporter. Therefore, to preserve paddy for a long time and maintain its quality, moisture content is crucial. Proper paddy moisture reduction requires careful attention and study of various components to prevent loss of quality of paddy grains, whether it is the quality of paddy before milling or the quality of rice obtained after milling.

Currently, the paddy moisture content measurement requires contact with the paddy or damaging the paddy sample to determine the moisture content in the grain, which causes damage. The paddy moisture content measurement using microwave does not require contact with the paddy and does not damage the paddy sample, so it is a popular method for measuring moisture content. There are many forms of measuring moisture content by using microwave, for example:

Paddy moisture analysis using microwave properties is an experiment on drying agricultural products using microwaves to reduce the moisture content of paddy using a microwave oven. The method is to increase the temperature inside the paddy grains in the microwave oven and dry them several times until the desired moisture content is achieved. This drying of the paddy grains reduces the moisture content of the paddy grains, but in the experiment, the more microwave power used, the more the paddy grains changed color and the longer the drying time [1].

Due to the important role of moisture content in grain storage, packaging, and transportation, a portable moisture meter using a microwave microstrip sensor has been developed. The device consists of three parts: a microwave circuit module, a real-time measurement module, and display software. This research proposes an improvement by optimizing the thickness of the paddy sample and increasing the temperature and humidity

(13.66–27.02% w.b.) at a frequency of 3 GHz in the moisture range of 13–30%. This instrument has the advantages of real-time, simple structure, easy operation, low cost, and portability. This research is expected to provide important reference data for real-time in-situ measurement of agricultural yields and is great significance for the development of intelligent agricultural equipment [2].

A study of paddy moisture measurement with reflection measurement was purposed that is analyzing between moisture content variation and reflected wave. The free space technique was selected by using a network analyzer and an antenna for measuring reflected wave from paddy sample. The experiment results are clearly about the different S_{11} and various moisture contents at frequency range 0.8 – 3 GHz [3].

A study on Yagi-Uda antenna for paddy moisture measurement was proposed by using simulation program to simulated antenna before fabricated antenna. A Yagi-Uda antenna operates at 2.4 GHz and tested Surin jasmine rice (RD15) at moisture content of 17% and 28.6%, respectively. The experiment found that the S_{11} values from paddy moisture measurement with fabricated antenna were different in the range of 0.3-1 dB [4].

This work proposes paddy moisture measurement by using the relationship of reflected wave values for measuring paddy moisture content without contact and without destroying the paddy. The objective of the study is to find the relationship between the scattering parameter S_{11} and paddy moisture content. The obtained frequency and the scattering parameter S_{11} values will be used to design a paddy moisture meter using the free-space method. The experiment used Thai Hom Mali rice as a sample. Firstly, record the relationship between S_{11} values and paddy moisture content from the experiment. Secondly, calculate the return loss and phase ratio of S_{11} and paddy moisture content for finding suitable linear equation. Finally, replace S_{11} value from measurement to moisture equation for determining

moisture content by using the experimental parameter before.

2. PRINCIPLE

Paddy moisture measurement uses a reflection measurement method to find the difference in waves reflected from empty air, a conducting plate, and a rice sample. This paddy moisture measurement consists of a display unit, a network analyzer, a transmission line, and an antenna. The network analyzer generates a frequency signal and receives the reflected signal. The transmission line transmits and receives the signal. The antenna transmits the incident wave to the paddy sample and receives the reflected wave back to the network analyzer for analysis. The display unit processes and displays the measured moisture value. Fig. 1 shows the display unit with a portable network analyzer that is a transmitter and receiver connected to the antenna. The incident wave is transmitted from the antenna to the surface of the paddy sample. After that, the reflection wave occurs between the air and the paddy sample while the transmitted wave propagates into the stack.

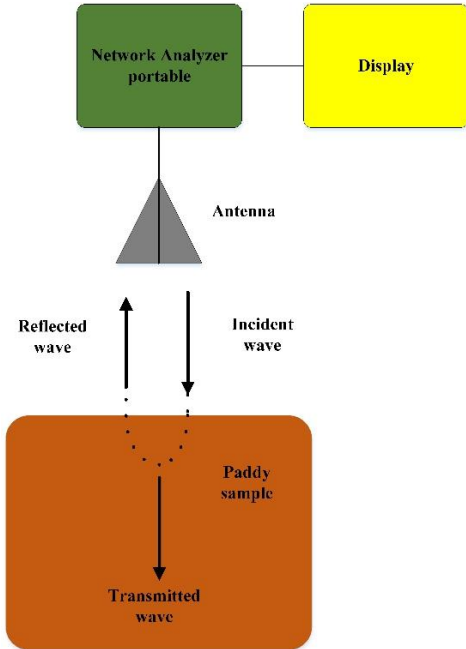


Fig. 1. Reflection measurement from paddy sample

This work offers paddy moisture content determination with reflection measurement by using free space method that transmitter and receiver are same position which an antenna is both transmitter and receiver. The distance between antenna and

sample are far-field, the plane wave illuminated to incidents on the paddy sample and reflects from the stack of paddy sample. The various paddy moisture content provide different reflection value that the measured reflected wave as the scattering parameter (S_{11}) from network analyzer. The complex reflection coefficient (Γ) is S_{11} , given as $\Gamma = x \pm jy$ [5], where it can find magnitude (dB) as

$$RL = -20\log|\Gamma| \quad (1)$$

where RL is return loss and also determine phase(degrees) as

$$\phi_{\Gamma} = \tan^{-1}(y/x) + n360^{\circ} \quad (2)$$

where n is integer, the relationship between (1) and (2) are R ratio with paddy moisture content [6] as

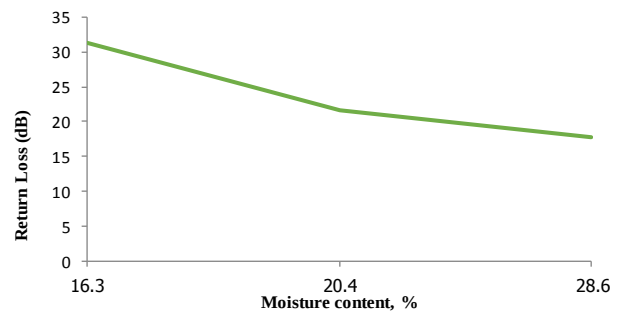
$$R = RL/\phi_{\Gamma} \quad (3)$$

This R ratio shows the relationship with the moisture content from the paddy measurement. The magnitude and phase values of S_{11} from the experiment will be collected to find the appropriate linear equations including slope and intercept on the vertical axis which are related to the different paddy moisture values. When the actual paddy moisture is measured, the S_{11} values will be processed by the display unit to get the percentage of paddy moisture.

3. RESULTS

3.1 EXPERIMENTAL RECORDING OF PADDY MOISTURE CONTENT AND REFLECTION AT 2.4 GHZ

The experiment to record the relationship between paddy moisture content and reflection is important. Research [3] found the relationship between paddy moisture content and reflection as shown in Fig. 2.



(a)

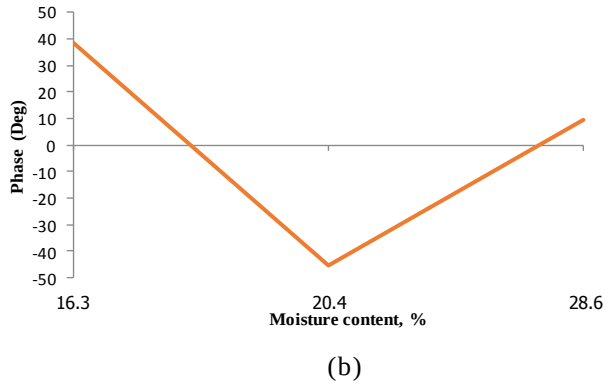


Fig. 2. Relationship between moisture content and reflection (a) return loss (b) phase

Fig. 2, it is found that the relationship between the paddy moisture content and the return loss value is that at low moisture content, the return loss is high and at high moisture content, the return loss is low. This can be used to analyze the ratio between the return loss and the phase of the reflection coefficient that is related to the moisture content of paddy as shown in Fig. 3.

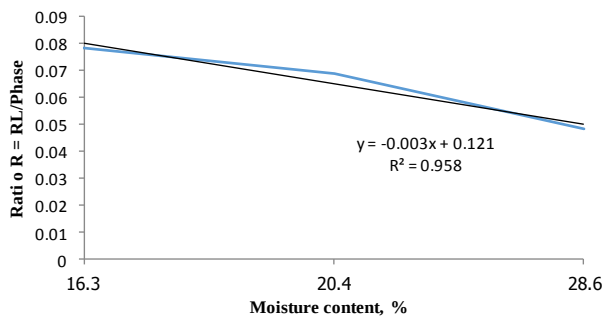


Fig. 3. R ratio for Thai Hom Mali rice samples in relation to moisture content.

From Fig. 3, the relationship between paddy moisture and R ratio is found to be a linear equation obtained from the experiment in the paddy moisture range of 16.3% to 28.6%, related to the R ratio value in the range of 0.04 to 0.09, where $y = -0.003x + 0.121$ and $R^2 = 0.958$, that is,

$$R_{exp} = m_{exp} (\%MC_{exp}) + C_{exp} \quad (4)$$

Where R_{exp} is the experimental ratio, m_{exp} is the experimental slope, $\%MC_{exp}$ is the experimental paddy moisture content, and C_{exp} is the experimental intercept value.

3.2 MEASUREMENT OF MOISTURE CONTENT OF THAI HOM MALI RICE AT A 2.4 GHz

Each 500 g of paddy samples were prepared at three moisture levels, at room temperature 25°C and

measured with a grain moisture meter to obtain values of 18.4%, 19.5% and 20.5%. The measurements were performed using a 2.4 GHz patch antenna connected to a portable network analyzer and the generated paddy moisture measurement program as shown in Fig. 4. and calculated moisture content using equation (5).

$$\%MC_{mea} = (R_{mea} - C_{exp})/m_{exp} \quad (5)$$

Where $\%MC_{mea}$ is the measured paddy moisture content, R_{mea} is the measured ratio, C_{exp} is the experimental intercept value, and m_{exp} is the experimental slope.

Table 1. Moisture content measurement of Thai Hom Mali rice

Grain meter (%)	Fabricated meter (%)	Error (%)
18.40	18.19	1.14
19.50	19.32	0.92
20.50	20.47	0.15



(a)



(b)

Fig. 4. Paddy moisture content measurement (a) Grain meter (b) Fabricated meter

Paddy moisture content measurement using a grain meter and fabricated meter is done three times and the values are averaged. From Table 1, the paddy moisture values were measured by the grain meter compared with the fabricated meter found that the moisture values of 18.40%, 19.50%, and 20.50% had errors of 1.14%, 0.92%, and 0.15%, respectively.

4. DISCUSSION AND CONCLUSION

This paper presents a non-destructive and non-contact paddy moisture measurement in paddy samples using microwaves. It relies on a measurement technique called the free space method. The measurement principle uses a single patch antenna as a transmitter and receiver connected to the S_{11} port of a portable network analyzer. The network analyzer is connected to a notebook computer programmed to read the measured data and display it as paddy moisture on the screen. Each measured value is calibrated with the air and the conducting plate measurement before calculating with equation (5). The experiment used the paddy moisture adjustment value in the range of 16.3%-28.6% which is related to the reflection coefficient value in the range of 0.027-0.129. This results in the consistency of low paddy moisture in relation to low reflection and high moisture in relation to high reflection. When the reflection coefficient is used to calculate the return loss, it is 17dB-32dB and the phase value of the reflection coefficient is between -50° and 50° . By comparing the ratio between the return loss and the phase value, the ratio R is obtained that is related to the paddy moisture, namely if comparing the consistency of low paddy moisture content, it will be related to high R ratio value and high moisture content will be related to low R ratio value. The linear equation from the experiment is $y = -0.003x +$

0.121 at $R^2 = 0.958$. This linear relationship is used to find the actual measurement value of paddy moisture content as in equation (5). The paddy moisture content from the test sample is in the range of 18.4%-20.5%, with an error of 0.15%-1.14%. This measurement does not take into account the change in temperature and thickness of the paddy sample.

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