Watermelon Quality Classification with Reflection Coefficient

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Abstract This paper proposes a study for watermelon quality classification with microwave. The object of this work is to develop a possible non-destructive means for ripeness detection based on the manner of reflection coefficient. In this study, we performed the S_{11} parameter estimation for immature and mature fruit as sample under tests in free space method and the frequency range 800 MHz to 3 GHz of network analyzer measurement. After that the suitable frequency is selected for design and fabrication. The experiment shows good separation of immature and mature watermelons which the mature fruit possess higher reflection coefficient than immature fruit.

Keyword Quality Classification, Non-destructive Means, Free Space Method, Reflection Coefficient

1. Introduction

Watermelon is one of popular fruits in the world which is planted worldwide. Generally, watermelon is harvested when it is mature with good taste but harvesting mature fruits have difficulty due to classification by expert, such as color, surface, knock, and so on. However, the experience is needed for this. Therefore, farmers need to employ expert for harvest fruits. Observing shape e.g. color or knock is a common method but sometimes it is not correct. Consequently, there is a need to have a sensor for monitoring maturity stage of watermelons. Although there are many non-destructive technique such as image processing [1], near infrared NIR [2], and so on. They are widely developed for fruit classification but the systems have the large size. Hence, in this work, we presented a simple sensor system that the implement measuring reflected signal from a generator, through a watermelon fruit, to a detector by using directional coupler. This experiment can discriminate between the immature and mature watermelons.

2. Principle and Design

In this study to determine the immature and mature watermelons have three main steps namely the S_{11} parameter estimation in wide band, single frequency is selected from obvious difference of S_{11} for design and fabrication, and the experiment.

Firstly, we analyzed the S_{11} parameter from network analyzer in the frequency range 800 MHz to 3 GHz of immature and mature fruit measurement as sample under tests in free space method. The measured results between immature (25 units) and mature (25 units) fruits we found that obvious difference of S_{11} at 2.45 GHz as 0.03 dB and 0.475 radians. Therefore, the frequency is selected at 2.45 GHz for the system design.

To illustrate a principle of reflected signal from a generator, through a watermelon fruit, to a detector by using direction coupler is shown in Fig.1. The distance of the sample is far-field ($2D^2/\lambda$, where D is dimension of sample and λ is wave length at operating frequency). The directional coupler is connected between signal generator (input port) and antenna (through port) that can detect signal (coupled port) at detector, another port is 50 Ω.

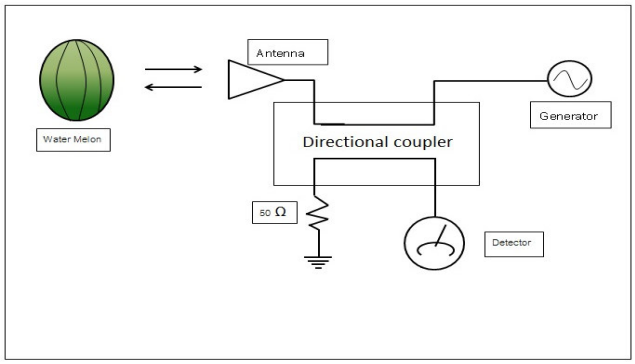

Fig.1. Principle of the proposed system.

From the measured results of watermelon [3] which can predict maturity stage, for example at 2.45 GHz, the dielectric constant and loss factor of immature fruit pulp are 68 and 12, respectively. Those for mature fruit pulp are 74 and 13, respectively. For the peel of watermelon has the dielectric constant and loss factor are 40 and 10, respectively. We can calculate reflection coefficient [4] by using thick peel of 1.2 cm and 1 cm from the different dielectric properties at 2.45 GHz as 0.75 and 0.76, respectively. The higher dielectric properties offer higher reflection coefficient.

Finally, we designed directional coupler (C = -20 dB) as in [5] at 2.45 GHz with the dimensions w =

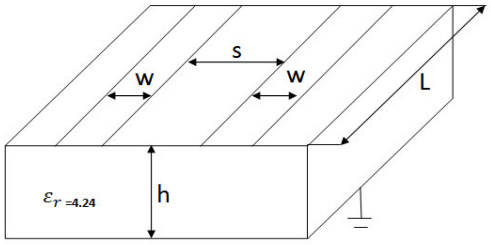

Fig.2. Directional coupler.

2.8 mm, s = 2.6 mm, and L = 2.05 mm. The directional coupler was fabricated on FR-4 PCB (ε_r = 4.24) with h = 1.414 mm are shown in Fig.2.

3. Results

The fabricated directional coupler has each port that is matched at 2.45 GHz with less than -10 dB and the coupling signal between input and couple port is -19.009 dB as shown in Table I.

Table I. Characteristics of directional coupler

Port	$\|S_{11}\|$ (dB)	$\|S_{21}\|$ (dB)
Input	-14.863	-
Through	-15.119	-1.738
Coupled	-10.734	-19.009
Isolated	-17.614	-20.531

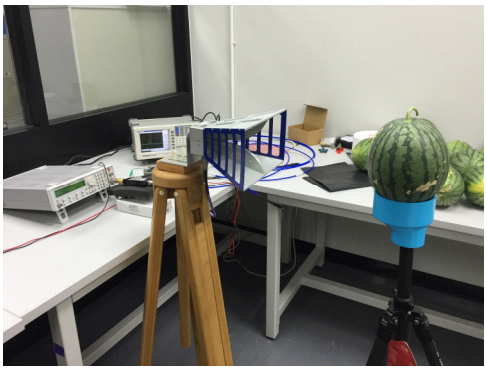

Fig.3. The experiment system.

The horn antenna (HA-08M18G-NF) is used as a watermelon measurement and a generator (HM8135) is used as a transmitter. The power signal of 0 dBm and 10 dBm were transmitted at 2.45 GHz. The signal is transmitted with a coaxial transmission line to a horn antenna. The distance from the horn antenna to the watermelon surface is 32 cm. The reflected signal from the watermelon is coupled by the directional coupler operating at 2.45 GHz. After that the coupled signal sent to detector by using spectrum analyzer (GPS-830).

Two groups of immature (25 units) and mature (25 units) fruits of Kinnaree watermelons that the sample dimension around 14 cm were measured by the proposed system as seen in Fig.3.

The results are shown in Table II. The reflection coefficient (Γ) is calculated from the calibration by placing a conductor plate on the fruit surface ($\Gamma = P_{measured}/P_{conductor}$). The power ($P_t$) of 0 dBm and 10 dBm, the averaged reflection coefficient difference between immature and mature fruits are 0.028 and 0.030, respectively.

Table II. Watermelons measurement

P_t (dBm)	Immature	Mature
0	0.882	0.910
10	0.915	0.945

According to the results, mature watermelons possessing higher dielectric constant provide higher the reflection coefficient than immature watermelons.

4. Conclusion

This work indicated that it is feasible to develop a non-destructive technique for measuring watermelon based on the feature of reflection coefficient. The proposed system for monitoring maturity stage of watermelons is designed by operating at 2.45 GHz. The reflected signal is detected by directional coupler and found that the mature watermelons provide higher the reflection coefficient than immature watermelons. The system can solve problem farmers to harvest watermelons before it is sent to market.

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