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Determination of Microwave Dielectric Properties of Grain by Free Space Transmission Method

자유공간 전송방법을 이용한 마이크로파 유전특성연구

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Abstract

A free space transmission method using X-band standard gain horn antenna is applied to measure the attenuation and phase shift of microwave signal through the wetted grain such as rough rice, brown rice and barley. The moisture content of grain varied from 11 to 25% based on its wetted condition. The dielectric constant and loss factor, which depend on the moisture content of the wetted grain are obtained from the measured attenuation and phase shift by vector network analyzer. The measured values of dielectric constants as a function of moisture density are compared with values of those obtained using the predicted model for estimating dielectric constants of grain.

1. Introduction

In the microwave frequency range transmission line method using a waveguide or a coaxial airline and resonant cavity method are mainly employed [1,2]. The disadvantages of this method are the requirement of the precise fabrication of the sample holders and the limitations of the non-contactive measurement. Otherwise, free space microwave measurement method is a very useful for on-line measurement of the moisture content [3-5].

In this paper the free space microwave measurement method using standard horn antennas is presented for determining the complex permittivity of grain which depends on the moisture content. A grain samples of rough rice, brown rice and barley with varying moisture content are used. The attenuation and phase shift of the microwave signal through the wetted grain samples are measured by HP8510C vector network analyzer in X-band frequency range. The complex permittivities of the wetted grain are calculated from the measured attenuation and phase shift for various values of moisture content. The measured values of dielectric constants as a function of moisture density are compared with values of those obtained using the predicted model for estimating dielectric constants of grain.

2. Microwave dielectric property

The interaction of the applied electromagnetic field with wetted grain can be described by the complex permittivity ;

$$\varepsilon = \varepsilon' - j\varepsilon'' \qquad (1)$$

The real part of the complex permittivity ε' is called the dielectric constant and the imaginary part ε" called the loss factor.

The dielectric constant is given as a function of the measured phase shift by

$$\varepsilon' = \left(1 + \frac{\Delta\Phi\lambda_0}{360d}\right)^2 \qquad (2)$$

where ΔΦ is the difference between the phase shifts with and without grain samples, λ_0 is the wavelength in free space and d is thickness of the sample, and the loss factor is obtained by

$$\varepsilon'' = \frac{\Delta A\lambda_0\sqrt{\varepsilon'}}{8.686\pi d} \qquad (3)$$

where ΔA is the difference between the attenuation with and without grain samples.

3. Free space measurement setup

A block diagram of the experimental setup used to measure the attenuation and phase shift of microwave signal through the grain samples is shown in Fig.1.

In this setup, a pair of a X-band standard gain horn antenna with 7.9cm x 5.4cm and 16.5dB gain are mounted on an acrylic plate stand. The horns are connected to the two ports of the HP8510C network analyzer via waveguide/coaxial adaptors.

Between the transmit and receive horns the sample holder is mounted. The sample holder is a rectangular container made of acrylic plates with 2mm wall thickness.

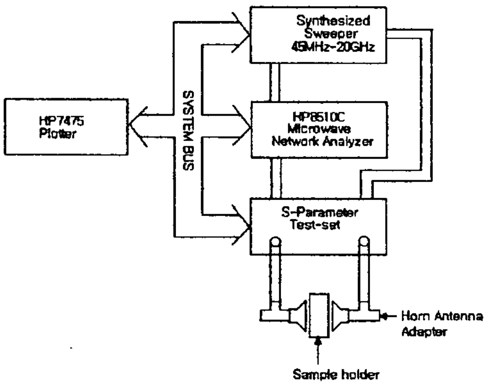


Figure 1: Block diagram of microwave free space measurement setup

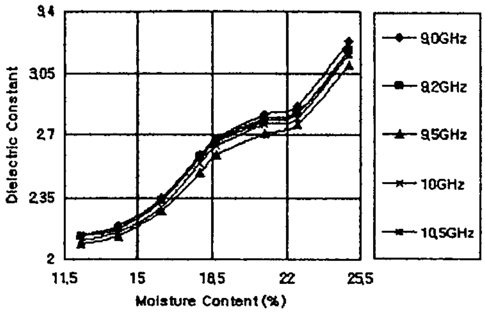
The width of the sample holder must be large enough to cover the signal between the antennas and the thickness of that be greater than one wavelength for using the wave propagation method. The dimensions of the sample holder used in this experiment are 42.5mm thickness, 119.6mm width and 155.2mm height.

4. Experimental results

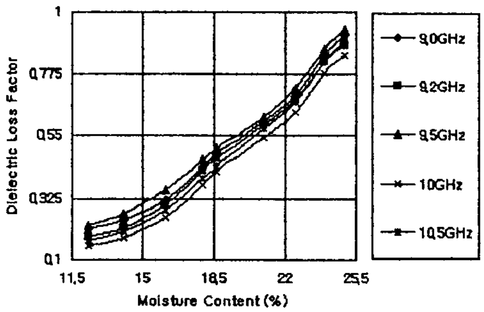
For this work, short grain rough rice, brown rice and barley were harvested in 1996 at a farm attached to the college of agriculture and life science at Seoul National University. The grain samples with several moisture contents are prepared for the measurement by a standard forced-air oven method. In this standard oven method, the moisture content is determined by drying grain samples with 10g weight for 24hours at 135°C [6].

The dielectric properties of grain with various moisture contents are determined by measuring the attenuation and phase shift of the microwave signal through the grain samples in the frequency range from 9.0 to 10.5GHz. The grain samples are naturally filled in the sample holder and the bulk density of samples varied from 0.546 to 0.606g/cm^3 for rough rice, from 0.777 to 0.808g/cm^3 for brown rice and from 0.627 to 0.697g/cm^3 for barley at the temperature 24°C respectively.

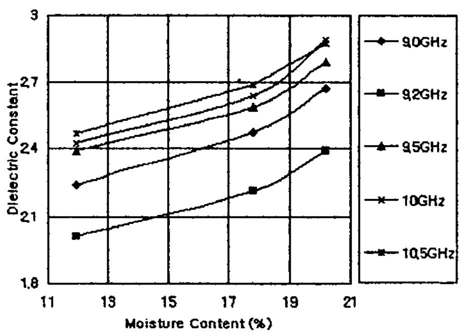
The variation in the dielectric constant and loss factor of grain samples of rough rice, brown rice and barley with various moisture contents is illustrated in Fig. 2 in the frequency range from 9.0 to 10.5GHz. The dielectric constant and loss factor are found to increase with the moisture content.



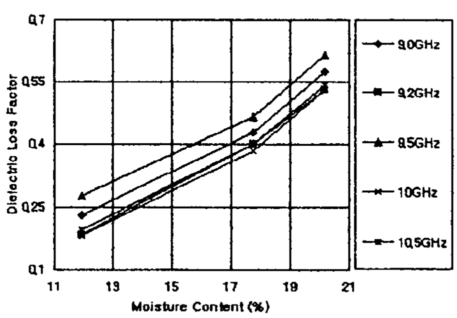
(a-1) Dielectric constant for rough rice



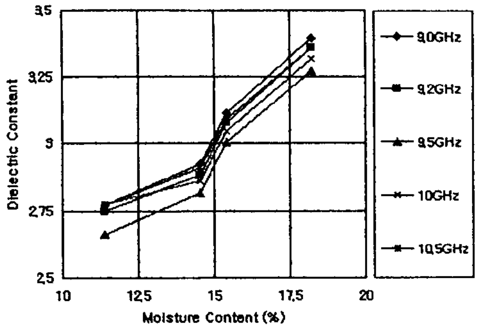
(a-2) Dielectric loss factor for rough rice



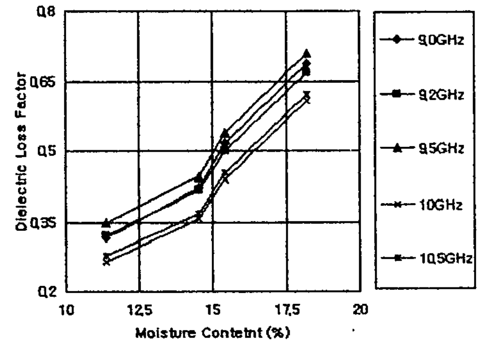
(b-1) Dielectric constant for brown rice



(b-2) Dielectric loss factor for brown rice



(c-1) Dielectric constant for barley

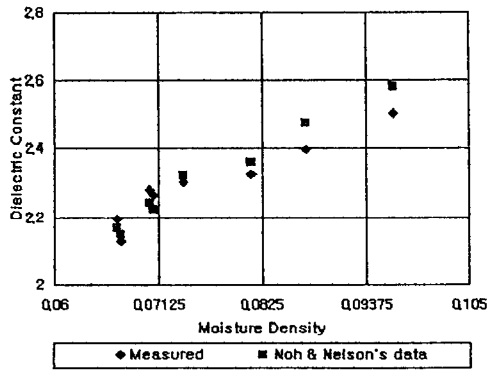


(c-2) Dielectric loss factor for barley

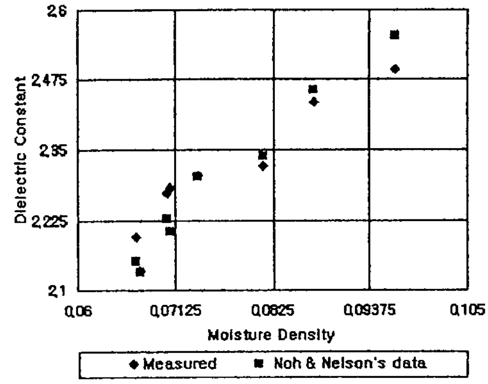
Figure 2: Moisture content dependence of the dielectric properties of (a) rough and (b) brown rice and (c) barley samples

The measured values of dielectric constants as a function of moisture density are compared with values of those obtained using the predicted quadratic model for estimating dielectric constants of rough rice as shown in Fig. 3 [7].

The comparisons of measured and predicted values of dielectric constant at the frequency of 9.0 and 10.5 GHz show that the measured values are in good agreement with the predicted quadratic model.



(a) at 9.0GHz



(b) at 10,5GHz

Figure 3: Comparison of measured and predicted values of dielectric constant as a function of moisture density with prediction model at (a) 0.9 and (b) 10.5GHz.

5. Conclusions

Dielectric constants and loss factors of rough rice, brown rice and barley with moisture content in the range of 11 to 25% are determined from the measured attenuation and phase shift of the transmitted microwave signal through the grain samples using vector network analyzer.

The measured dielectric constant and loss factor are in good agreement with those obtained using the prediction model for estimating dielectric constants of rough rice.

References

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