Frequency Optimization for Dynamic Measurements of Wide-range Moisture Content using Microwave

Seitaro KON† Masahiro HORIBE† and Yuto KATO†

†Research Institute for Physical Measurement, National Metrology Institute of Japan,

National Institute of Advanced Industrial Science and Technology

AIST Central 3, 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8563 Japan

E-mail: †seitaro-kon@aist.go.jp

Abstract This paper describes dynamic and static measurement methods for wide-range moisture content of agricultural products such as rice and silage. The proposed method uses the attenuation and phase shift of the microwave transmitted signal through a microstrip transmission line (MSTL) sensor. The results of dynamic measurements of rice samples with low moisture content(< 18 %) showed close agreement with those of static measurements. Furthermore, the proposed method showed possibility to measure the silage samples with high moisture content (69.8 % to 79.5 %). To optimize the measurement frequency, the linearity between moisture content and slope (dB/radian) were evaluated. As a result, the best linearity was obtained at 2.46 GHz.

Keyword Dynamic measrurement, Microstrip transmission line, Microwave, Transmission characteristics, Phase shift, Moisture content

1. Introduction

The moisture content in agricultural and livestock products is an important quality factor for export and import trade. The moisture meters commonly-used are based on dc resistance measurement and radio-frequency (RF) capacitance measurement. The RF capacitance measurement method can achieve non-destructive measurements of moisture content. In addition, the transmission line methods using waveguide, coaxial lines, and resonant cavities have been reported for measurements of moisture content in agricultural products such as rice, wheat, and fruits [1-5]. These methods require bulk density for a measurement of moisture content. However, the bulk density accounts for variations in a measurement of moisture content. Therefore, a measurement method of moisture content which does not require the value of bulk density for dynamic measurements is expected. This paper describes a dynamic and static measurement method of wide-range moisture content using a microstrip transmission line (MSTL) sensor and its optimization of measurement frequency.

2. Measurement Setup

A MSTL is used to measure the attenuation and phase shift of the microwave signal. In the measurement setup, both ends of the MSTL are connected by coaxial cables to the two ports of a vector network analyzer (VNA). The moisture contents of low-moisture rice samples and high-moisture silage were measured and controlled by the oven-dry method.

The MSTL was tipped and connected to the calibrated VNA for dynamic measurements. Firstly, transmission characteristics were measured for the MSTL without the samples. And then, samples were flowed on the tilted MSTL during dynamic measurements. In the static measurements, samples are placed on the MSTL directly.

3. Measurement Results

A relationship between amplitude change and phase shift was measured. They have proportional relations for all rice samples with different moisture contents in spite of different amount of rice on the MSTL [6]. As shown in Table 1, results of dynamic measurements have close agreement with those of static measurements.

Figure 1 shows the relationships between slope (dB/radian) and moisture content of rice samples.

Table 1 Results of dynamic and static measurements of low-moisture rice samples at 3 GHz.

Moisture content (%)	Slope (dB/radian)	
	Static measurement	Dynamic measurement
12.2	1.21	1.19
15.1	1.40	1.41
17.5	1.45	1.46
18.0	1.50	1.46

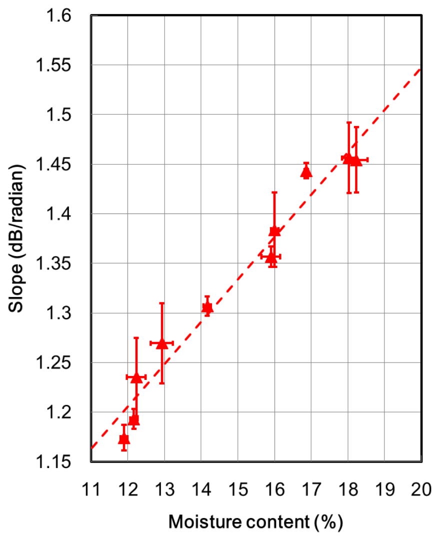

Fig.1 A relationship between moisture content of rice and slope (dB/radian)

The slope is linearly dependent on the moisture content of rice. It means that a dynamic measurement of moisture content of rice samples was achieved.

However, moisture contents of rice were limited up to 18 %. Therefore, high-moisture silage samples such as corn, rice, and sorghum are measured by proposed method.

Figure 2 shows measurement results of high-moisture silage with moisture contents of 69.8 %, 71.7 %, and 79.5 % at different frequencies.

It is difficult to distinguish between silage with moisture content of 69.8 % and that of 71.7 % at 3 GHz. On the other hand, at 920 MHz, the silage with moisture content of 69.8 % and 71.7 % are distinguishable but measurement of the silage with moisture content of 79.5 % was difficult.

Therefore, measurement frequency should be optimized for measurements of high-moisture silage. Figure 3 shows frequency dependence of measurement results of high-moisture silage. As you can see, it is impossible to use the frequency lower than 1 GHz and higher than 3 GHz to measure the high-moisture silage. To optimize the measurement frequency, the linearity between moisture content and slope are evaluated as shown in Fig.4. As a result, the optimized frequency for measurements of high-moisture silage was 2.46 GHz.

4. Conclusion

The dynamic and static measurement method of wide-range moisture content using MSTL was proposed. The results of dynamic measurements of

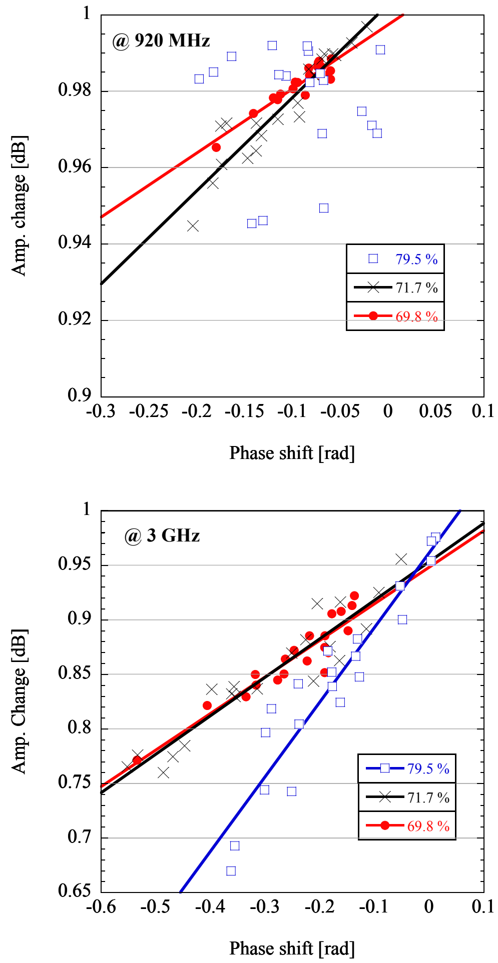

Fig.2 Measurement results of high-moisture silage with different frequencies.

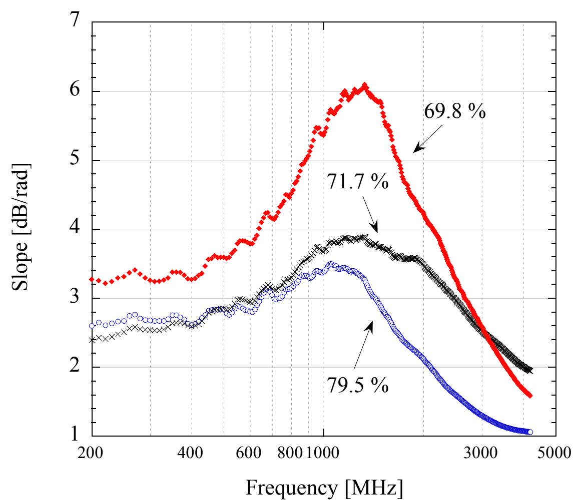

Fig.3 Frequency dependence of measurement results of high-moisture silage with moisture contents of 69.8 %, 71.7 %, and 79.5 %.

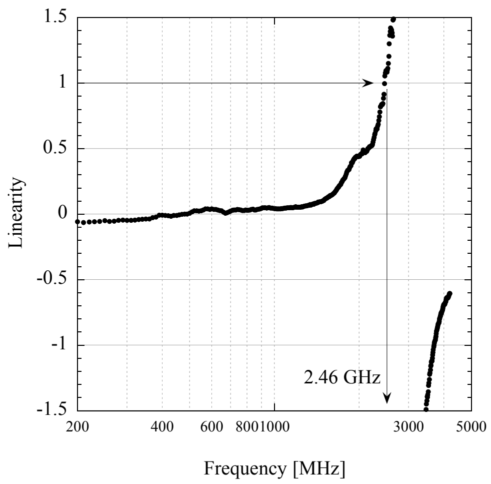

Fig.4 Frequency dependence of linearity between moisture content and slope.

low-moisture rice samples showed close agreement with those of static measurements. The slope (dB/radian) is linearly dependent on the moisture content of rice samples up to 18 %.

Furthermore, the proposed method showed possibility to measure the high-moisture silage samples with moisture content up to 79.5 %. To optimize the measurement frequency, the linearity between moisture content and slope are evaluated. As a result, the best linearity was obtained at 2.46 GHz.

Our future work will estimate the measurement uncertainties of those measurements and improve the structure of MSTL sensor to achieve a wide-range dynamic measurement of multiple agricultural products.

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