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REFLECTION TECHNIQUE FOR ESTIMATION OF MOISTURE HEVEA RUBBER LATEX CONTENT USING RECTANGULAR PATCH ANTENNA

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ABSTRACT

In this paper, the designed microstrip patch antenna is employed to study reflection technique and predict moisture content of Hevea Rubber Latex. The rectangular patch sensor was designed to operate at microwave frequency range from 0.1 to 5 GHz on a RT/Duroid substrate with 6.15 ±0.015 permittivity and 1.27 mm thickness. The width and length of the rectangular patch antenna was 18 mm and 38 mm, respectively. The phase shift reflection coefficient, $\Delta\Theta$ of rubber latex are obtained with moisture content at all selected frequencies. Estimation equations phase shift of reflection coefficient as a function of moisture content were developed at several selected frequencies. These equations were used to predict the amount of moisture content on Hevea latex based on the measured phase of reflection coefficient, φ using Agilent Professional Network Analyzer N5230A (PNA). The actual values of moisture content were obtained using standard oven drying method. The lowest mean relative error between actual and predicted moisture contents was 0.04 at 1 GHz.

Keywords: *rectangular patch antenna, reflection coefficient, Hevea Rubber Latex, moisture rubber content*

INTRODUCTION

Microwave technology has been developed rapidly to determine moisture content. The determination of moisture content, *m.c.* is an important quality feature that directly influences storability of many raw materials, foods and agricultural. Besides that, it also influences the economic loss which is due to decreases in saleable weight during long-term storage of product [1]. The natural rubber latex is complex biological product containing 50-80% of water, 15-45% of rubber hydrocarbon and approximately 2-4% of non-rubber constituents [2]. In the rubber industrial production, the amount of water content is very important which Hevea rubber latex brings on a high demand which leads to high price. Hevea rubber latex, especially for natural rubber is one of the important consumption producing the national export contribution exceeds RM13.28 billion in 2011 [3].

Various techniques have been proposed to determine the dry rubber content, total solid content and moisture content in Hevea latex. Some of these include an experimental study based on titration method [4], Buoyancy method [5] and microwave measurement techniques [6, 7]. The standard an oven drying method [8] was used in this work to determine actual moisture content. Unfortunately, all the techniques are too time consuming and laborious.

Recently, several new microwave sensors and supporting algorithms have been explored for the determination of moisture content in tropical agricultural products [9-13]. However, this article presents the application of microstrip patch antenna in the determination of moisture content in Hevea latex in the frequency range between 100MHz and 5 GHz. The objective in this article is to establish the relationship between phase shift of the sensor and moisture content in Hevea latex.

MATERIALS AND METHODS

The proposed patch antenna sensor was designed using Microwave Office version 7.03. The resonant frequency was at 3.2 GHz. The sensor was fabricated using a RT/Duroid substrate with 6.15 permittivity and

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1.27 mm thickness. The width and length of rectangular patch were 18 mm and 38 mm, respectively. A 50 ohm SMA female connector was used as the feeding port of the microstrip.

The fresh hevea latex samples were obtained from Universiti Putra Malaysia's Research Park. The mass of fresh and diluted latex samples were recorded using electronic balance and dried into microwave laboratory oven at 70±C for 24 hours [14]. The dried samples were kept at room temperature before weighing again until it reaches a constant value. The actual moisture content was determined using standard an oven drying method [8].

$$\text{Moisture content (\%)} = (m_{wet} - m_{dry}) / m_{wet} \times 100\% \qquad (1)$$

where m_{wet} and m_{dry} are the initial and final mass before and after drying.

The experimental setup consists of a designed rectangular patch antenna and Hevea latex samples with various percentages of moisture contents. The Professional Network Analyzer (PNA) was used to measure the reflection coefficient of the sensor with and without the samples in frequency range between 0.1-5 GHz. The calibration procedure was performed using Agilent's Calibration Kit 85052D (open, short and load standards) from 0.1 GHz to 5 GHz to establish a 50 ohm calibration plane between the sensor and the coaxial cable. .

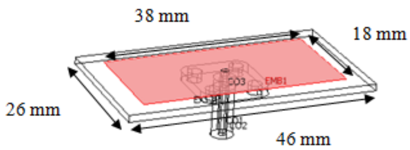

Fig. 1: The design schematic of the microstrip patch antenna

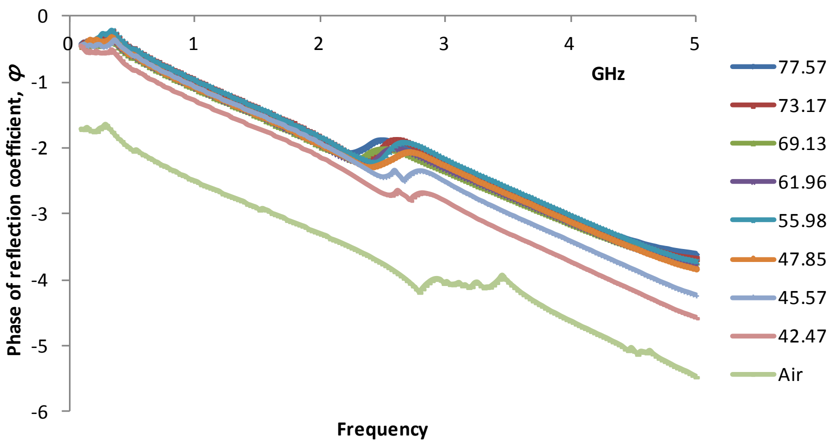

Fig. 2: Variation in the phase of reflection coefficient, φ with frequency for various percentages moisture content of Hevea rubber latex.

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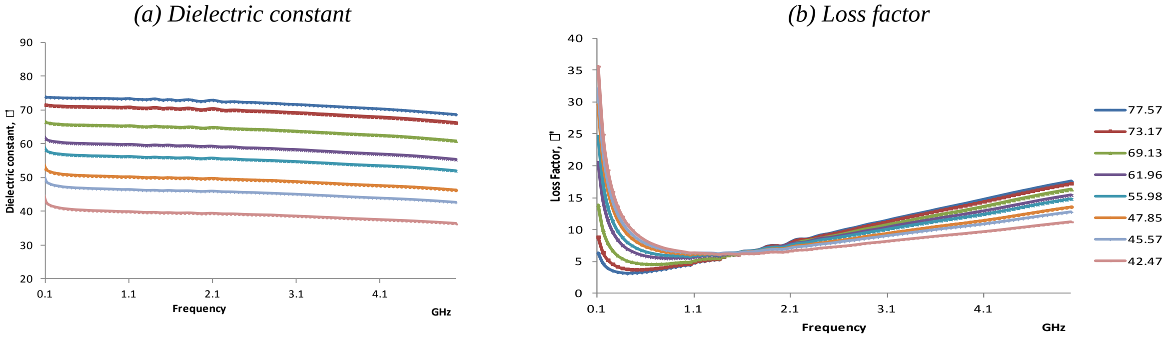

Fig. 3: Variation in Dielectric constant (a) and loss factor (b) with frequency for various percentages moisture content of Hevea rubber latex.

RESULTS AND DISCUSSIONS

The variation in the measured phase, φ of the reflection coefficient with frequencies of the unloaded (air) and loaded sensor with Hevea rubber latex of various *m.c.* from 42.47 % to 77.57 % with frequencies range between 0.1 GHz to 5 GHz are illustrated in Figure 2. It shows all φ of samples follow the profile of air. These φ slightly fluctuated in ranging from 0.1 GHz to 0.3 GHz. It can be related with slightly decreases of dielectric constant in this range as shown in figure 3(a).

The measured resonance frequency of the unloaded sensor (air) was similar to the calculated frequency using Microwave Office at 3.2 GHz. From 2.3 GHz to 2.7 GHz, the phase shifted to lower *m.c.* of Hevea Latex. The figure also shows that φ of each sample sudden increases to higher φ at resonant frequency themselves. For moist materials, the maximum absorption of microwave energy occurs at resonant frequency approximately from 2.3 GHz to 2.7 GHz [15]. The resonance peaks of the loaded sensor were shifted to the left from 3.2 GHz to 2.3 GHz corresponding to 42.47% to 77.57% moisture content. Variation in *m.c.* will result in a variation in the permittivity of the sample which in turn will lead to a variation in the effective permittivity of the sample loaded microstrip patch sensor that have been shown in figure 3(a) and (b). Finally, this will also lead to a variation in the resonance frequency of the sensor.

The reduced phase of reflection coefficient, φ samples at frequencies higher than 3.2 GHz were probably due to sudden increase in the values of the dielectric loss factor of the material. Calibration equations were established relating the phase of reflection coefficient, φ to moisture content at some selected frequencies as listed in Table 2.

The accuracy of the calibration equations were determined by comparing the actual and predicted moisture contents as shown listed Table 2. The relationship between predicted and actual values of moisture content is best represented by calibration equation at 1 GHz with the highest sensitivity = 0.17 and lowest mean relative error 0.04.

Table 1: Comparison between actual values and predicted moisture content for 1 GHz, 2 GHz, 3 GHz, 4 GHz and 5 GHz

Actual moisture content	**Predicted moisture content**				
	1 GHz	**2 GHz**	**3 GHz**	**4 GHz**	**5 GHz**
77.57	83.33	83.56	86.19	88.42	85.17
73.17	73.86	79.09	80.87	84.55	76.52
69.13	67.65	69.24	74.04	81.37	66.79
61.96	67.85	73.26	71.24	76.32	65.79
55.98	56.37	60.87	56.76	66.86	51.19
47.85	49.65	46.74	42.44	42.59	41.30
45.57	45.38	41.61	51.53	52.45	49.24
42.47	39.83	32.42	21.09	41.70	53.37
Mean relative error	0.04	0.10	0.14	0.13	0.07

Table 1: Calibration equation of phase shift, regression coefficient and sensitivity for 1 GHz, 2 GHz, 3 GHz, 4 GHz and 5 GHz

frequency (GHz)	**calibration equation**	**Regression coefficient, R^2**	**sensitivity**
1	$y = -17.362x + 2638.6$	0.87	0.17
2	$y = -12.119x + 1272.5$	0.88	0.12
3	$y = -3.3087x + 341.56$	0.71	0.03
4	$y = -6.1723x + 287.12$	0.86	0.06
5	$y = -3.317x + 84.764$	0.87	0.03

CONCLUSIONS

A microstrip patch antenna for rapid and accurate measurement of moisture content in Hevea latex has been successfully used to determine moisture content in latex based on reflection measurement. The accuracy of sensor was determined by comparing the predicted moisture content with the actual moisture content using oven drying. The moisture content predicted by using microstrip patch antenna has been proved with mean relative error below 5%.

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