



**UNIVERSITI PUTRA MALAYSIA**

**DEVELOPMENT OF MICROCONTROLLER-BASED DUAL  
DIRECTIONAL COUPLER MICROWAVE SYSTEM TO MEASURE  
MOISTURE CONTENT OF HEVEA RUBBER LATEX**

**AHMAD MOHAMMADI**

**FS 2009 5**



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DIRECTIONAL COUPLER MICROWAVE SYSTEM TO MEASURE  
MOISTURE CONTENT OF HEVEA RUBBER LATEX**

By

**AHMAD MOHAMMADI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirements for the Degree of Master of Science**

**July 2009**



**Dedicated**

**To**

**This thesis is dedicated to my beloved wife, Mahtab Mohammadi, to my dear mother Zahra Khoshkeif, my dear father Ramazan Mohammadi and my dear sister Afsaneh Mohammadi that I owe them all of success in my life.**



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in  
Fulfilment of the Requirement for the Master Degree

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**Chairman: Professor Kaida Khalid, PhD**

**Faculty: Science**

The rubber industry is one of the most important industries in South-East Asian countries and moisture content determination is the main parameter for quality inspection and process control. Developing digital, portable, accurate chip and measurement instruments certainly facilitates the trading and helps the growth of the industry. It is important that true moisture content of the rubber latex can be determined correctly and instantly to ensure a fair price quotation is given to the tapper at the rubber collection center on the same day.

This thesis describes the development of digital, portable, rapid, simple to operator, chip and accurate microwave instrument to determine the total solid content (TSC) or moisture content (MC) of hevea rubber latex using microcontroller, dual directional coupler, and open-ended coaxial sensor. Various coaxial sensors were



simulated using FEMLAB to study the reflection coefficient of the sensor corresponding to the total solid content of hevea rubber latex. The performance of the fabricated open-ended coaxial sensor was tested using Vector Network Analyzer (VNA) and the results then compared with commercial HP 85070B flanged sensor.

The Microwave Office 2001 (MWO) was used to simulate the Dual Directional Coupler (DDC). The developed DDC was operated at 5 GHz which gave the high correlation between dielectric properties and moisture content of latex. S-parameters of the fabricated DDC were measured using VNA and they compared satisfactory to theoretical simulations.

One coaxial voltage controlled oscillator was used as the signal source in the sensor system at 5 GHz. Two coaxial detectors were used to measure the coupled and reflected signals in this system. The calibration equation which relates the measured output voltages from detectors and TSC of latex was found.

The whole sensor system was interfaced to an ATmega16 microcontroller. Based on the calibration equation and set-zero point, software program of the microcontroller was developed using BASCOM-AVR software to follow by calculation setup, calibration, and display the value of TSC on the LCD. The whole system was tested using diluted rubber latex with different TSCs at room temperature (25°C) and the results from standard oven drying method and this study were found in good agreement with the accuracy and reproducibility at the level of less than 0.5%.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk Ijazah Master Sains.

**Pembinaan meter mikrogelombang lembapan menggunakan pengawal mikro**

Oleh

**AHMAD MOHAMMADI**

**July 2009**

**Pengerusi: Professor Kaida Khalid, PhD**

**Fakulti: Sains**

Tesis ini memperihalkan tentang pembangunan alat gelombang mikro digital untuk menentukan jumlah kandungan pepejal (TSC) atau kandungan lembapan (MC) dalam susu getah dengan menentukan pengawal mikro, penganding dual aruhan, dan sensor talian sepaksi terbuka dihujung. Pelbagai sensor sepaksi telah disimulasikan dengan menggunakan FEMLAB untuk mempelajari pekali pemantul sensor yang sepadan dengan jumlah kandungan pepejal (TSC) dalam susu getah (hevea). Pencapaian sensor talian sepaksi terbuka yang dihujung direka telah diuji dengan menggunakan penganalisa rangkaian vector (VNA) dan keputusan telah dibandingkan dengan flanged sensor HP 85070B.

Microwave Office (MWO) telah digunakan untuk mensimulasikan penganding Dual-Aruhan(DDC). Pembangunan DDC telah dioperasikan pada 5 GHz mengikut

kepada korelasi tinggi diantara sifat dielektrik dan kandungan lembapan susu getah dalam frekuensi ini. Parameter-S daripada rekaan DDC telah diukur dengan menggunakan VNA dan mereka telah membandingkan kepuasar produk terhadap simulasi teori. Satu voltan sepaksi dikawal oleh pengayun telah digunakan sebagai punca isyarat dalam sistem sensor pada 5GHz. Dua pengesan sepaksi telah digunakan untuk mengukur isyarat gandingan dan isyarat pantulan dalam sistem ini.

Persamaan kalibrasi yang berhubungkait telah diukur voltan keluarannya daripada pengesan dan TSC daripada susu getah telah dikenalpasti. Keseluruhan sistem sensor adalah diantaramukakan pada satu produk pengawal-mikro ATmega16 keluaran syarikat Atmel. Berdasarkan kepada persamaan kalibrasi dan titik set-sifar, program perisian daripada pengawal-mikro telah dibangunkan dengan menggunakan perisian penyusun C untuk mengikut set pengiraan, kalibrasi, dan paparan nilai TSC pada LCD.

Sebagai satu contoh aplikasi, keseluruhan sistem diuji dengan menggunakan susu getah yang dicairkan dengan berbeza TSCs yang berbe pada suhu bilik dan keputusan daripada kaedah piawai pengeringan ketuhar, dan penyelidikan ini didapati bertepatan dengan nilai  $R^2=0.998$ .

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I certify that a Thesis Examination Committee has met on 28 July 2009 to conduct the final examination of Ahmad Mohammdi on his thesis entitled " Development of Microcontroller-Based Dual Directional Coupler Microwave System to Measure Moisture Content of Hevea Rubber Latex " in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Sciences.

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## **DECLARATION**

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

---

**AHMAD MOHAMMADI**

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## LIST OF ABBREVIATIONS

DRO	Dielectric Resonant Oscillator
VCO	Voltage Controlled Oscillator
VNA	Vector Network Analyzer
MMIC	Monolithic Microwave Integrated Circuit
DRC	Dry Rubber Content
MUT	Material Under Test
MC	Moisture Content
TSC	Total Solid Content
VSWR	Voltage Standing Wave Ratio
TEM	Transverse Electric Magnetic Fields
TE	Transverse Electric Mode
TM	Transverse Magnetic Mode
RF	Radio Frequency
HF	High Frequency
VHF	Very High Frequency
UHF	Ultra High Frequency
VB	Visual Basic
DDC	Dual Directional Coupler
FEM	Finite Element Method
FEMLAB	Finite Element Method Laboratory
MOM	Method of Moment
FDTD	Finite Different Time Domain



PTFE	Polytetrafluorethylene (Teflon)
MATLAB	Matrix Laboratory
d.b.	Dry Basis Moisture Content Determination
w.b.	Wet Basis Moisture Content Determination



## LIST OF SYMBOLS

$E$	Electric Field Intensity	(V/m)
$H$	Magnetic Field Intensity	(A/m)
$\epsilon_0$	Permittivity of Vacuum	(F/m)
$\mu_0$	Permeability of Vacuum	(H/m)
$\epsilon_r^*$	Relative Permittivity (Complex )	(dimensionless)
$\mu_r^*$	Relative Permeability (Complex )	(dimensionless)
$\eta^*$	Medium Impedance (Complex)	( $\Omega$ )
$L$	Inductance	(H)
$C$	Capacitance	(F)
$R$	Resistance	( $\Omega$ )
$G$	Conductance	(S)
$X$	Reactance	( $\Omega$ )
$B$	Susceptance	(S)
$Z$	Impedance	( $\Omega$ )
$Y$	Admittance	(S)
$\gamma^*$	Propagation Constant (complex)	(1/m)
$\alpha$	Attenuation constant	(1/m)
$\beta$	Phase Constant	(rad/m)
$\delta$	Skin Depth	(m)
$\sigma$	Conductivity	(S/m)
$\omega$	Angular Frequency	(rad.Hz)
$\epsilon'$	Dielectric Constant	(F/m)

$\varepsilon''$	Loss Factor	(F/m)
$\tan\delta$	Loss Tangent	(dimensionless)
$\Gamma^*$	Reflection Coefficient (complex)	(dimensionless)
$\tau^*$	Transmission Coefficient (Complex)	(dimensionless)
$D$	Directivity	(dimensionless)
$e$	Efficiency	(dimensionless)
RL	Return Loss	(dB)
$S_{11}$	Scattering Parameter (Port 1 to Port 1)	(dB)
$S_{21}$	Scattering Parameter (Port 1 to Port 2)	(dB)
$S_{31}$	Scattering Parameter (Port 3 to Port 1)	(dB)
$S_{41}$	Scattering Parameter (Port 4 to Port 1)	(dB)

# CHAPTER ONE

## INTRODUCTION

### 1.1 Introduction

Knowledge of the moisture content of agricultural materials is a great importance in industrial and commercial applications. Moisture content of hevea latex is one of the most important parameters which determines the quality of the latex. The most widely recognized methods for moisture measurements are based on drying known weights of material in ovens and calculating moisture content from the loss in weight. This method is simple and has been employed as the standard method for calibration of moisture-testing equipment. However, this method is not practical used because it is time-consuming.

Various portable instruments and sensors have been developed using technology such as microwave, infrared, laser, electrical capacitance, and ultrasound. Microwave method has been used by many researchers to determine the moisture content in agricultural materials. These include the work by Nelson (Nelson, 1982, 1991, 1996), Kraszewski (Kraszewski and Nelson, 1994, 1996), and Khalid (Khalid, 1982) who determined the dielectric properties and moisture content in fresh fruits, soybean seeds, and hevea rubber latex.





However, latex moisture meter which is available today is still without a digital version. A digital version of the meter will give better accuracy, stability, and rapid readout. For this purpose a microcontroller will be used to develop the digital latexometer.

This chapter gives an overview of the hevea rubber latex. Microwave aquametry and the benefit of microcontrollers are briefly introduced. Section (1.5) describes the state of the art in latex moisture content measurement. Finally the objectives of this study and the scope of the thesis are stated at the end of the chapter.

## **1.2 Hevea Rubber Latex**

Hevea Rubber Latex is one of the main agricultural products of Malaysia. As shown in Figure 1.1 it is a viscous liquid harvested by tapping of rubber tree. The fresh latex consists of 55-80% water, 15-45% rubber hydrocarbons and approximately 2-4% of non carbon constituents (Chin, 1979). This composition varies widely according to season, weather, soil condition and tapping system. Normally 0.3 -0.5% ammonia is added as preservative to fresh latex because the fresh latex is highly perishable material and without preservative it will coagulate after few hours. Field latex can be concentrated to higher rubber constant to make it more uniform and economically more attractive. The latex used in this study was concentrated rubber latex supplied by Rubber Research Institute of Malaysia, (RRIM). The present standard of latex