DESIGN OF PLANAR MICROWAVE SENSOR RESONATOR FOR MATERIAL CHARACTERIZATION

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

Specially dedicated to my beloved family and friends for supporting me to finish this project. A huge thanks for my supervisor Professor Dr. Zahriladha bin Zakaria giving me the guidance and treat me with full patience throughout the process to finish my final year project.

ABSTRACT

Nowadays, microwave sensor are gaining popularity in applications of food industry, agriculture and biomedical. Among the potential techniques, microwave resonant technique has been commonly applied in dielectric material characterization measurement. Conventionally, non-planar sensors such as waveguide, dielectric and coaxial resonators which provide high sensitivity and accuracy are being used in the measurement. However, the sensors have drawbacks including bulky in size, high cost manufacturing and consume high volume for detection of the previous sample of material under test (MUT). Hence, planar microwave resonator sensors which are compact in size, low cost and ease of fabrication are invented. However, the planar sensors suffer with low sensitivity and Q-factor value which limits the range for material characterization. As a result, this project designs a planar microwave sensor resonator with the operating frequency between 2GHz and 5GHz via computer simulation technology (CST) software and overcome the weakness of the sensor. The design of the structure resonator based on the mathematical equation and optimization of the parameter value.

ABSTRAK

Kini, penderia gelombang mikro semakin popular dalam aplikasi industri makanan, pertanian dan bioperubatan. Antara teknik yang berpotensi, teknik resonan gelombang mikro telah biasa digunakan dalam pengukuran pencirian bahan dielektrik. Secara konvensional, penderia bukan satah seperti pandu gelombang, resonator dielektrik dan sepaksi yang memberikan kepekaan dan ketepatan tinggi sedang digunakan dalam pengukuran. Walau bagaimanapun, penderia mempunyai kelemahan termasuk saiz besar, pembuatan kos tinggi dan menggunakan volum tinggi untuk pengesanan sampel bahan dalam ujian (MUT) sebelumnya. Oleh itu, penderia resonator gelombang mikro planar yang bersaiz padat, kos rendah dan kemudahan fabrikasi dicipta. Walau bagaimanapun, penderia planar mengalami kepekaan rendah dan nilai faktor Q yang mengehadkan julat untuk pencirian bahan. Hasilnya, projek ini mereka bentuk resonator penderia gelombang mikro satah dengan frekuensi operasi antara 2GHz dan 5GHz melalui perisian teknologi simulasi komputer (CST) dan mengatasi kelemahan penderia tersebut. Reka bentuk resonator struktur berdasarkan persamaan matematik dan pengoptimuman nilai parameter.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

MUT :	Material Under Test
CST :	Computer Simulation Technology
VNA :	Vector Network Analyzer
PCB :	Printed Circuit Board
PM :	Perturbation Method
TM :	Transverse Magnetic
TE :	Transverse Electric
VC :	Empty Cavity
VS :	Specimen Volume
GHz :	Giga Hertz
MHz :	Mega Hertz
Hz :	Hertz
HFSS :	High Frequency Structure Simulator
WHC :	Water Holding Capacity
CSRR :	Complementary Split Ring Resonator
SSRR :	Symmetrical Split Ring Resonator
BMSSR:	Bridge Multiple Split Ring Resonator
DGS :	Defected Ground Structure
SMA :	Sub Miniature version A
EM :	Electromagnetic
UV :	Ultraviolet
DUT :	Device Under Test
SUT :	System Under Test
GUI :	Graphical User Interface
IoT :	Internet of Things
RM :	Ringgit Malaysi

S21(dB):	Insertion Loss
S11(dB):	Return Loss
μ_0 :	Permeability
BW :	Bandwidth
f_c :	Resonant Frequency without Sample
f_s :	Resonant Frequency with Sample
Q :	Quality Factor
f_r :	Resonance Frequency
Δf_r :	Resonance Frequency Shifting
$\Delta\mu$:	Permeability Changes
$\Delta\varepsilon$:	Permittivity Changes
V :	Perturbed Volume
E_0, H_0 :	Field Distribution without Perturbation
E_1, H_1 :	Field Distribution with Perturbation
ε_r :	Dielectric Constant
ε_r' :	Actual Permittivity
ε_r" :	Imaginary Part of Permittivity
μm :	Micrometer
mm :	Millimeter
f_o :	Operating Frequency
ε_{eff} :	Effective Permittivity
c :	Speed of Light
W :	Width of Transmission Line
L :	Length of Transmission Line
h :	Height of Substrate in Datasheet
λg :	Wavelength of Coupling Gap
L_s :	Length of Substrate
W_s :	Width of Substrate

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Microwave resonator sensor are one of the most widely used groups of people and have been extensively used for the material characterization in the field of agriculture, medications and industrial. Material characterization is playing an important role in investigating the properties of the material, which can be characterized depending on the sensitivity of a microwave sensor resonator.

This project is aimed to design a sensor with high precision, high sensitivity and narrow band frequency. The advantages of this sensor which are low cost, more accurate, high sensitivity, compact size, ease of handling, and environmentally friendly make this type of microwave resonator sensor can compete with the previous research studies.

In order to validate the performance of the proposed sensor, different types of materials with a known dielectric constant will be tested. This microwave resonator sensor aiming of high Q-factor > 100 value with a better performance. This propose sensor will be extracting with mathematical analysis for determining the specifications parameter of designing the sensor. Then, it will simulate through the computer simulation technology (CST) software.

Therefore, this proposed sensor is ease handling of fabrication process and low-cost project with greater accuracy and sensitivity which make this microwave resonator sensor specials than others. The material used for the substrate prototype sensor is low cost and environmentally friendly. By comparing the S-parameter of simulation and vector network analyzer (VNA) measurement, the sensor will validate through the 50 SMA-Connector port at the microwave resonator sensor transmission line.

1.2 Problem Statement

In order to popularize the usage of microwave sensor resonator, the sensors need to have low manufacturing cost and simple design structure. In addition, the sensors also need to be small in size to bring more convenient to the users.

Non-planar microwave resonator sensor is basically possing high sensitive detection and precise measurement. However, drawbacks such as high manufacturing cost, complex design structure, and bulky size do exist.[1][4] If non-planar microwave resonator sensor is applied in industrial applications, it will be a waste of money due to the high cost, difficulty in mass production due to the complex design structure and space consuming because of the uncontrollable large size of it.[1][2]

Definitely, planar microwave resonator structure has become the alternative method in sensor developing to produce a sensor which are compact, low cost, and easy to integrate with other electronic components.[1][3][[4] However, this structure suffers from poor quality factor and low sensitivity,[3] which restrict the usage in

industrial application of monitoring quality and safety of food, pharmaceutical and etc. Therefore, in this project, a planar microwave sensor resonator with high sensitivity and accurate measurement is designed in the material characterization. By applying a narrow bandwidth of insertion loss, high quality factor can be produced and hence the limitations of conventional planar microwave resonator sensor can be solved.

1.3 Objectives

This project's main goal is to design a resonator sensor with high quality factor for the material characterization. The specific objective of the project has been stated as below:

- To design a planar microwave sensor resonator.
- To fabricate the sensor designed on a printed circuit board.
- To validate and analyze the sensor designed.

1.4 Scope of Work

The prototype of the microwave sensor is produced by using microstrip planar transmission line technique which are compact in size, ease of fabrication, low cost and easy handling. The propose sensor will be operate at 3.5 GHz in ranges from 2 GHz to 5 GHz. Computer Simulation Technology (CST) software will be used to design and simulate the planar microwave sensor resonator. The sensor designed is more focus on solid material characterization. The base area of the prototype made should be within 6cm × 6cm. The prototype will be fabricated by using RT 5880, and then validated through experimental measurement via Vector Network Analyzer