DESIGN OF PLANAR MICROWAVE SENSOR TO DETECT PERMITTIVITY OF UNKNOWN MATERIAL

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To my beloved parents Mohd Noor Bin Yusoff and Kholisah Binti Che Omar, my Supervisor and my friends. Thank You So Much.

ABSTRACT

Planar microwave resonant sensor is a device that use to measure using microwave frequency that is considered one of the most precision and sensitivity than other methods. Most of the resonator are intended to detect permittivity of material in particular application areas such as food quality control, medical, bio-sensing and others. These day, some products on the business sectors and shopping centers have prohibited or unhealthy ingredients that can effect on consumers health. The planar structure experiencing from poor Q factor and low sensitivity, which inhibit the usage wide industrial applications. Therefore, complementary split ring resonator (CSRR) is use to verifying and identifying the dielectric properties in material and it is produce higher Q-factor with ability to destroy the undesired harmonic imitation. The main purpose of this project is to identify, simulated and measure a device that can identify material properties in terms of permittivity, resonant frequency and quality factor. For experimental verification, CSRR sensor with 2.64GHz is design using full wave electromagnetic solver which the CST Microwave Studio use for simulation. The sensor are design and fabricated on 0.508 thick RT/Duroid 4350b substrate, and testing is carried out using network analyzer.

ABSTRAK

Planar microwave resonans sensor adalah peranti yang digunakan untuk mengukur gelombang frekuensi mikro yang dianggap tepat dan peka dari kaedah yang lain. Kegunaan resonator ini bertujuan untuk mengesan permittivity bahan dan digunakan dalam pelbagai bidang dan aplikasi tertentu seperti kawalan mutu makanan, perubatan, bio-sensing dan lain-lain. Sejak kebelakangan ini, kualiti produk yang dijual di pasar raya tidak barang yang terlarang dan tidak segar dan boleh memudaratkan kesihatan. Struktur planar yang digunakan sebelum ini mempunyai Q-faktor yang lemah dan kepekaan yang rendah dan menyebabkan penggunaan aplikasi perindustrian terbantut. Oleh itu, complementary split ring resonator(CSRR) digunakan untuk mengesahkan dan mengenalpasti sifat-sifat dielektrik dalam bahan dan menghasilkan Q-faktor yang lebih tinggi dengan keupayaan untuk memerangkap harmonik yang tidak diingini. Tujuan utama projek ini adalah untuk mengenal pasti, mensimulasikan dan mengukur dielektrik bahan yang boleh mengenalpasti sifat-sifat bahan dari segi permittivity, frekuensi resonan dan faktor kualiti. Sensor CSRR direka mengunakan 2.64GHz dengan menggunakan perisian Studio Microwave CST untuk simulasi. Sensor ini direka dan direka pada 0.508 tebal RT / Duroid 4350b substrat, dan ujian dilakukan menggunakan penganalisis rangkaian.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

CSRR	:	Complementary Split Ring Resonator
CST	:	Computer Simulation Technology
VNA	:	vector network analyzer
SIW	:	integrated waveguide
SRR	:	split ring resonator
MUT	:	Material under test
VNA	:	vector network analyzer

LIST OF APPENDICE

CHAPTER 1

INTRODUCTION

This chapter present the objectives and motivation of this project and the scopes of this research work to give idea of the expected results. Besides that, background of the project and problem statement are also described here. This chapter ends with an overview of the thesis organization.

1.1 Background

Nowadays, material characterization are important role in microwave engineering and others industries. There are several material characterization techniques available for determination of permittivity and permeability. The resonant methods mostly provide quite accurate parameter extraction from the others characterization techniques, mainly for low loss samples than other techniques. The resonant technique must place the sample at the maximum magnetic or electric field position to determine

dielectric permittivity. Although, dielectric characterization using resonant method have need large and expensive metal cavities but resonant method have advantages such as low cost, ease of fabrication and easy integration with other monolithic integrated devices [1].

Some groups are currently exploring the planar resonant sensors for material characterization. Newly, there are several types resonant sensor are use such as substrate integrated waveguide (SIW) [2], the complimentary split ring resonator (CSRR) [3] and the split ring resonator (SRR) [4] have been proposed. CSRR and SRR based resonant sensors are frequently use because simple fabrication process and more compactness in design. The resonant cavity perturbation is usually the most accurate technique for low loss materials. The information about the dielectric properties of materials based on the adjustment in the measured resonant frequency and quality factor [5]. Generally, the cavity resonators technique have been used for characterize of the dielectric properties of the MUT.

Lately, complementary split ring resonator (CSRR) have been use in resonant sensor to characterize the dielectric constant of the material under test [6]. There are many advantages such as the low cost manufacturing, convenience, presence non-invasive and easy to prepare. Conversely, permittivity part are not consider by previous paper in term of the effect of air gap between the test specimen and the planar structure. However, the CSRR rectangular design have been use by researcher to measuring the dielectric properties of materials.

Next, to create an empirical formula for calculating the relative permittivity and permeability of the magneto-dielectric samples, the numerical method are used to measured resonant frequency and the transmission coefficient of the loaded sensor.

The prototype is fabricated on the 0.508 mm thick Rogers 4350b substrate using frequency 2.64GHz. The electromagnetic simulation tool which the CST Microwave Studio is use to presents the measurement results and to analyze the result. The fabricated prototype is measure using vector network analyzer (VNA) to collect the data.

1.2 Problem Statement

There are various microwave resonators sensor such as coaxial cavity, dielectric, and waveguide resonators have been used for material characterization. Microwave resonator is use because it has high sensitive detection and accurate in measurement. However, these types of sensors have problems which that high manufacturing cost, complex design structure, and bulky size. Thus, planar microwave sensor structure is suggest as the alternative to develop sensors with other electronic components [7] . Unfortunately, the planar structure experiencing poor Q-factor and low sensitivity, which limit the utilization wide industrial applications such as pharmaceutical, biomedical and beverage industries [8].

Therefore, a new structure of planar microwave sensor for determining and detecting the dielectric properties in common solids is present to create higher Q-factor with ability to overcome the undesired harmonic spurious. The presented sensor is based on complementary split ring resonator (CSRR) structure by using the perturbation theory which the dielectric properties of the resonator affects the Q-factor and resonance frequency of the resonator sensor.

1.3 Objectives

The objectives of this study are as follow.

i. To identify the conductivity of material properties through Planar Microwave Sensor.
ii. To design and measure the dielectric properties through electromagnetic simulation in the terms of permittivity, frequency and quality factor of unknown material.
iii. To validate and compare the simulated result through experimental setup and evaluation in laboratory.

1.4 Scopes

The main purpose of this project is to design microwave sensor using Complementary Split Ring Resonator (CSRR) and characterize and determine material properties through electromagnetic simulation in terms of permittivity, resonant frequency and quality factor. This study to fabricated the sensor and validate the prototype performances at 2 .64GHz and simulation using Computer Simulation Technology (CST) software. Fabrication in laboratory using Roger 4350B material and measurement using Vector Network Analyzer (VNA) are going to be performed in this study. Comparison between simulation results and measurement results are taken in this project with well known the standard or permittivity of materials by considering the thickness of the tested materials.

1.5 Thesis outline

Chapter 1 describe a brief introduction and explaining of the important material characterization to detect permittivity of material, problem statement, objectives, scope and of study.

Chapter 2 studies the previous research and discuss the literature review related to the project and highlighted the important topics.

Chapter 3 explains the methods involved and describe the details of the equipment, material and apparatus used to complete the research.