UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF MICROSTRIP MICROWAVE SENSOR FOR FLUID CHARACTERIZATION USING COMPLEMENTARY SPLIT RING RESONATOR (CSRR)

This report is submitted in accordance with the requirement of the Universiti
Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering
Technology (Telecommunication) with Honours.

by

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TECHNOLOGY

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Development of Microstrip Microwave Sensor for Fluid Characterization Using Complementary Split Ring Resonator (CSRR)**

SESI PENGAJIAN: **2018**

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APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Telecommunication) with Honours. The member of the supervisory is as follow:

Signature: ……………………………………………….
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Signature: ……………………………………………….
Co-supervisor: MOHD ERDI BIN AYOB

ABSTRAK

Sensor gelombang mikro adalah pilihan yang sangat menarik untuk banyak aplikasi elektronik, bioperubatan dan perindustrian. Mereka menawarkan banyak kelebihan termasuk sensitiviti tinggi, kekukuhan dan kos fabrikasi dan pengukuran yang rendah. Sensitiviti yang tinggi dan pengenalpastian tepat bagi sampel cecair kimia dan biologi menggunakan resonators dielektrik dan silinder ketebalan telah dikaji dan ditunjukkan. Dalam kajian ini, bahagian utama peranti ini adalah mikrostrip yang ditambah "*complementary split-ring resonator*" (CSRR). CSRR menghasilkan medan elektrik yang kuat dalam jurang dan cincin. Peranti ini direka untuk beroperasi pada frekuensi di sekitar 2 GHz. Oleh itu, ia memenuhi keperluan alat-alat sensitiviti tinggi yang kos rendah dan padat dalam aplikasi sensor microstrip mikro. Untuk mengukur dengan cara menitiskan sampel cecair pada cincin mengubah frekuensi resonans dan puncak pengurangna CSRR resonans. Sensor microstrip memerlukan sampel yang sangat kecil. Konsep sensor gelombang mikro yang dicadangkan adalah serasi dengan platform "lab-on-a-cip" kerana ketepatannya.

ABSTRACT

Microwave sensors are very attractive choices for many of electronic, biomedical and industrial applications. They offer many advantages including high sensitivity, robustness and low fabrication and measurement cost. High sensitivity and accurate identification of chemical and biological liquid samples using microwave dielectric and cylindrical resonators have been studied and demonstrated. In this paper, the main part of the device is a microstrip coupled complementary split-ring resonator (CSRR). The CSRR produced a strong electric field in a gap and the ring. The device is designed to operate at around 2 GHz. So it, satisfies the need for low-cost and compact high sensitivity devices in microwave microstrip sensor applications. The liquid sample drop at a ring modifies the resonance frequency and peak attenuation of the CSRR resonance. The microstrip sensor requires a very small amount of sample. The proposed microstrip sensing concept is compatible with lab-on-a-chip platforms owing to its compactness.

DEDICATION

Special dedication to my beloved parents,

MOHD RAZIF BIN ALI

&

MISKIAH BINTI HAMID

My family members and my friends

Thank you for all your care, support and believe in me

ACKNOWLEDGEMENTS

First and foremost, all praise and gratitude to Allah SWT for giving me strength to went through all difficulties and hardship to successfully finishing up my thesis. I wish to express my sincere appreciation to my beloved supervisor, Pn. Aziean binti Mohd Azize for valuable experience, encouragement, guidance, critics and friendship. I would also to thank you to PM Dr. Mohamad Zoinol Abidin bin Abd Aziz for his contribution and knowledge in finishing this project.

I want to show my appreciation to my beloved parent, Mohd Razif bin Ali and Miskiah binti Hamid and all my family members for all their supports, motivations and pray from the initial of the project until end of it. Last but not least, special thanks to my friends especially Muhammad Fahmi Izzat bin Abdul Latiff and others that help and non-stop supporting in completing the project.

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SRR	Split Ring Resonator
CSRR	Complementary Split Ring Resonator
CST	Computer Simulation Technology
GHz	Giga Hertz
VNA	Vector Network Analyzer
MHz	Mega Hertz
TEM	Transverse electromagnetic
SUT	Sample under test
MUT	Material under test
NRW	Nicolson, Ross and Weir
HFSS	High Frequency Structure Simulator
FR-4	Flame Retardant – 4
UV	Ultra violet
PCB	Printed Circuit Board

CHAPTER 1

INTRODUCTION

1.1 Introduction

The material properties at microwave frequencies develop and start at the 1950s. Along the development of the characterization, there new technique and measurement methods had formed. Several techniques were designed based on materials that want to measure (LF Chen, 2004). Material characterization currently used in industrial development with a precise measurement. It because highly accurate, more compact, being cost effective and also used to assess the quality and identify in the bio sensing, food industry and agriculture. The bio sensing was to determine the properties of cells and tissues in human body. To meet the needs of consumers, the use of precise measurement methods is indispensable in the food industry. And lastly for agriculture, it help to improve the quality of agriculture based on the determination of bulk density and moisture in the soil composition. All the industry relate with the dielectric properties based on content of moisture in the food and agriculture. The investigative work or researchers will analyses the permittivity of the glucose solution based on changes in the glucose concentration. There have some techniques that can be designed include the non-resonator and resonator methods that state by (AA Boybay, 2012).

The non-resonant methods, it can used to determine the electromagnetic properties (PM Narayanan, 2014). It more accurate to measure the dielectric properties with any frequency on it. For the resonant method, this technique can measure dielectric with a higher degree of accuracy (AK Jha, 2014). It also can provide a better sensitivity.

For this paper work, investigated a design of sensor for materials characterization. The single split ring resonator (SRR) that combine with microstrip transmission line is the basic sensor for the materials characterization. It designed based on a high Q factor. In this paper work, the design that used is Complementary Split Ring Resonator (CSRR). It produced a powerful electric field in a small area. It also can produced a high sensitivity of dielectric property surrounding the materials.

1.2 Problem Statement

Health care is very important nowadays. People can get negative impact based on what the kind of food that they eat or drink. There is not have a specific sensor the measure the composite of materials. Each material have a permittivity, so the sensor have to develop the measure it. There have a difficult part to measure the permittivity of material. The microwave microfluidic sensor is proposed in this paper. The complementary split-ring resonator (CSRR) is appropriate to design for sensing applications. This device also is very useful because it have engaged in various system and applications but more to microfluidic sensing. In addition this device can used in medical industry to control and monitor the specific chemical. So, microwave microfluidic sensor provides a very useful information that can improve the design, processing, quality and control of product.

1.3 Objectives

The aims of this projects were to study about microstrip sensor and to develop a device that can identify material or a sample of liquid properties. Therefore, the objectives that should be achieved is:

- To design and simulate the microstrip sensor by using Computer Simulation Technology (CST) software.
- To fabricate the microstrip sensor for various liquid measurement sensing.
- To analyze the material properties based on measured on electromagnetic in terms of frequency, return loss and quality factor (Q-factor).

1.4 Project Scope

The main purpose for this project is to develop a device which is by using microwave microfluidic sensor to identify a material properties based on electromagnetic simulation in terms of frequency, permittivity and quality factor. This device sensor is to determine the permittivity of liquids based on changes in the peak attenuation and resonance frequency of the transmission response which is S_{21} on resonance. Design a metamaterial-based microfluidic sensor with single split-ring resonator (SRR) coupled microstrip line and it designed to operate at around 2.1 GHz and by do the simulation on Computer Simulation Technology (CST) software, fabrication in laboratory and measurement by using Vector Network Analyzer (VNA) that are going to be performed in this case study.

1.5 Thesis Structure/Organization

This thesis is organized as follows:

i. Chapter 1: Introduction – This chapter presents a general introduction of this projects, the objectives of this projects and also about microstrip sensor will be discussed.

ii. Chapter 2: Literature Review – This chapter presents a detailed background of microstrip sensor and methods that used to identify material properties. It also provides information about microstrip sensing and also methods that are used to characterize material properties.

iii. Chapter 3: Methodology – This chapter presents about the methods and procedure that to use for design this projects in details. This chapter will consists a flow charts, discuss about technique and also processing technique.

iv. Chapter 4: Results and discussion – This chapter presents illustrates and analyzes the simulation and experimental results of this projects and discusses the possible further improvements for developed this device.

v. Chapter 5: Conclusion and recommendation – This chapter presents the conclusion of the project. It also have some recommendation for future to develop the device.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Microwave are radio waves that have a specifics frequency at each wavelength from at the range as a short as one millimeter (frequency of 300 GHz) to given that one meter (300 MHz). The microwave frequency band or frequency spectrum allocation based on Figure 2.1 which is the framework of the whole electromagnetic spectrum. The wavelength, λ in free space that can be derived to *c*/*f*. Based on the derivation, c is represent speed of light in vacuum which is $3 \times 10^8 m/s$, and f represent of frequency. However, the velocity can be reduced by the factor $1/\sqrt{\varepsilon_r}$, this is condition when in a medium other than free space, where ε_r represent to relative dielectric constant of the medium. So, the wavelength, λ can also form $(\frac{1}{\sqrt{\varepsilon_r}})(\frac{c}{f})$ that can be defined and for the phase form it can use 2π radians (360°).

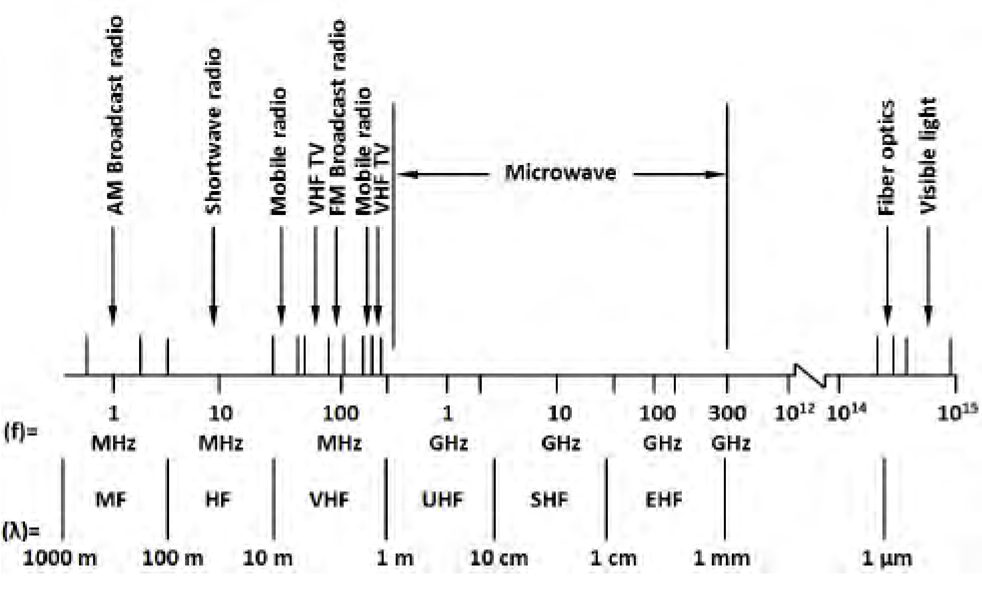

Figure 2.1: The frequency spectrum or electromagnetic spectrum for electronic engineering.

There have a two oscillating wave fields in the transverse electromagnetic waves which is electric and magnetic. The oscillating is perpendicular to each other and on the propagation direction based on Figure 2.2.

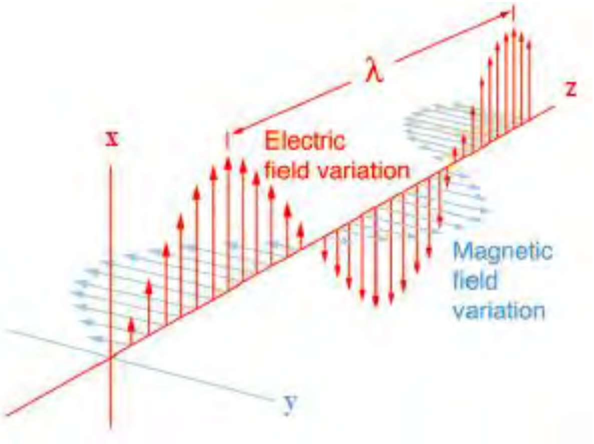

Figure 2.2: Electromagnetic waves that have a propagating electric and also magnetic fields.

Based on Figure 2.2, it show electromagnetic wave. The electric field vector will be exist on x-axis so it will become E_x has a finite value, but the value of E_y and E_z are zero. For the z-axis, noticed that there is no field component. The wave for the direction of propagation (z-axis) is called transverse electromagnetic (TEM). For the electric field component, E_x and magnetic field component which is H_y it will vary sinusoidal in space and also in time, represented by:

$$E_x = E_0 \sin(\omega t - \beta z) \tag{2.1}$$

$$H_y = \frac{E_0}{Z_0} \sin(\omega t - \beta z) \tag{2.2}$$

Where E_0 is represent to the electric field amplitude, wave impedance, Z_0 and wavenumber (rad/m), β can be expressed by following equation respectively:

$$Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 377\Omega \qquad (2.3)$$

$$\beta = \frac{2\pi}{\lambda} \qquad (2.4)$$

Where μ_0 and ε_0 are permeability and permittivity of free space, respectively.

This method which is microwave signals have been used for a various scientific and in industrial applications for the innovation. These include control and sensing, material processing, wireless communication, pharmaceutical applications and biomedical engineering.

There have some reason why the microwave resonators is used in sensing and application. Firstly, there have no physical contact. So, it have advantages compare with traditional techniques for the dielectric properties of a sample under test (SUT). Besides that, the sensors do not have any requirement for markers or labels and it fast and non-invasive. Furthermore, it totally fully compatible. After that, it can penetrate deeply inside material or it called high penetration depth except for iron or metals. Lastly, for the low power levels, microwave sensors are safe and non-destructive.

2.2 Fundamentals of Wave Propagation

By Maxwell's equation can be describe for wave phenomena and can be described in general form:

$$\nabla \times \underline{H} = \underline{J} + \frac{\partial D}{\partial t} = \underline{J} + j\omega\underline{D} = \sigma\underline{E} + j\omega\varepsilon\underline{E} = \underline{J} + \underline{J_d} \qquad (2.5)$$

$$\nabla \times \underline{E} = -\frac{\partial \underline{B}}{\partial t} = -j\omega\underline{B} = -j\omega\mu\underline{H} \qquad (2.6)$$

$$\nabla \cdot \underline{D} = \rho_v \qquad (2.7)$$

$$\nabla \cdot \underline{B} = 0 \tag{2.8}$$

The quantities electric field intensity, V/m ($\underline{E}$), magnetic field intensity, A/m ($\underline{H}$), electric flux density, C/m^2 ($\underline{D}$), magnetic flux density, Wb/m^2 ($\underline{B}$), conduction current density, A/m^2 ($\underline{J}$), displacement current density, A/m^2 ($\underline{J_d}$) and volume charge density, C/m^3 (ρ_v) that are related by the following relations:

$$\underline{D} = \varepsilon \underline{E} \tag{2.9}$$

$$\underline{B} = \mu \underline{H} \tag{2.10}$$

$$\underline{J} = \sigma \underline{E} \tag{2.11}$$

Formula for free space is $\mu = \mu_0 = 4\pi \times 10^{-7}$H/m and permittivity, $\varepsilon = \varepsilon_0 = 8.854 \times 10^{-12}$ F/m, and furthermore $\sigma = 0, J = 0$ and $\rho_v = 0$. Wave equation can be performed by combine the Maxwell's equations that leads to another set of equations. These wave equations is for lossless and lossy media are:

$$\nabla^2 \underline{E} = \mu_0 \varepsilon_0 \frac{\partial^2 \underline{E}}{\partial t^2} \qquad \text{(Lossless media)} \tag{2.12}$$

$$\nabla^2 \underline{H} = \mu_0 \varepsilon_0 \frac{\partial^2 \underline{H}}{\partial t^2} \qquad \text{(Lossless media)} \tag{2.13}$$

$$\nabla^2 \underline{E} = \mu\sigma \frac{\partial \underline{E}}{\partial t} + \mu\varepsilon \frac{\partial^2 \underline{E}}{\partial t^2} \qquad \text{(Lossy media)} \tag{2.14}$$

$$\nabla^2 \underline{H} = \mu\sigma \frac{\partial \underline{E}}{\partial t} + \mu\varepsilon \frac{\partial^2 \underline{H}}{\partial t^2} \qquad \text{(Lossy media)} \tag{2.15}$$