DESIGN AND DEVELOPMENT OF MATERIAL CHARACTERIZATION SYSTEM USING MICROWAVE SIGNAL

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

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Design and Development of Material Characterization System Using Microwave Signal

Sesi Pengajian : 2018/2019

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I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

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DEDICATION

Specially dedicated to my family:

Mr.Plendran Arjunan

Mr Balan

Mrs Rajeswary

Dr. Poovarasi

Mrs Premavathy

Mr Gobinathan Manickam

Who have encouraged, guided and inspired me throughout of my journey

Mr.Mathialagan Vengadeson

Ms.Narmatha Priya

Dr Sam Weng Yik

& supervisor

PM Dr Zoinol Bin Abdul Aziz

ABSTRACT

Material characterization system is needed to characterize the dielectric properties of the materials. A free space transmission and reflection (T/R) material characterization system is designed to study dielectric properties of wood, FR-4, acrylic, polystyrene and cardboard box. The project started with designing the material characterization system where material placed in between two antennas which are connected to Vector Network Analyzer (VNA) through cables. For characterization purpose, 2x2 microstrip antenna array designed at the resonant frequency 2.4GHz and with gain of 6 dB and 100 MHz of bandwidth. Measurement process carried out in each position of the material and measurement data obtained in reflection coefficient (S11) and transmission coefficient (S21) and analyzed using time-domain analysis. The calculated permittivity of five materials for S11 matches with reference value taken from reliable source. Wood material's calculated permittivity for the distance of 5cm is 2.7 falls within reference range 1.4-2.9 whereas for S21 is 3.8 do not match with it. On other hand, Radar Cross Section (RCS) analysis carried out using MATLAB visually observe the characterization of each material at range of frequencies. It can be concluded, the designed system can characterize material for S11 and S21 successfully for short range of distance only.

ABSTRAK

Sistem pencirian bahan diperlukan untuk mencirikan sifat-sifat dielektrik bahan. Sistem penyaringan bahan ruang bebas ruang dan balikan (T/R) direka untuk mengkaji sifat-sifat dielektrik kayu, FR-4, akrilik, polistirena dan kotak. Projek ini bermula dengan membentuk sistem pencirian material di mana bahan ditempatkan di antara dua antena yang disambungkan ke Vector Network Analyzer (VNA) melalui kabel. Untuk tujuan ini, 2x2 mikrostrip antena array direka pada frekuensi resonan 2.4 GHz dengan gandaan 6 dB serta 100 MHz jalur lebar. Proses pengukuran dilakukan pada setiap kedudukan data bahan dan pengukuran yang diperolehi dalam koefisien pantulan (S11) dan koefisien transmisi (S21) dan dianalisis menggunakan analisis domain waktu. Ketelusan yang dikira untuk lima bahan bagi S11 sama dengan nilai rujukan apabila dibandingkan. Ketelusan yang dikira untuk bahan kayu bagi jarak 5cm ialah 2.7 termasuk dalam julat rujukan 1.4-2.9 manakala bagi S21 adalah 3.8 tidak sepadan dengannya. Selain itu, analisis Radar Cross Section (RCS) yang dijalankan menggunakan MATLAB visual mengamati pencirian setiap bahan pada kekerapan frekuensi. Ia dapat disimpulkan, sistem yang direka bentuk boleh mencirikan bahan untuk S11 dan S21 berjaya untuk jarak pendek sahaja.

ACKNOWLEDGEMENTS

A humble gratitude to God for blessing me with the opportunity and strengthening to complete the work.

I would like to express my heartiest thanks to my worthy supervisor PM Dr Zoinol Abidin Bin Abdul Aziz whose encouragement, guidance and continuous support enabled me to carry out this project work. Indeed it is an honor for me to work with him.

I also would like to thank Mr Sufian and Mr Imran for helping me out during fabrication and measurement process. Without their help, I would not have completed my measurement process successfully.

Most importantly I would like to thank my family and my closest friends who have been very supportive past five years. Their understanding in term of moral support and financial were entirely significance towards my project and degree completion successfully.

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LIST OF SYMBOLS AND ABBREVIATIONS

AUT	:	Antenna Under Test
MUT	:	Material Under Test
S11	:	Reflection Coefficient
S21	:	Transmission Coefficient
VNA	:	Vector Network Analyzer
XRF	:	X-ray Fluorescence
d	:	Distance
RCS	:	Radar Cross Section

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CHAPTER 1

INTRODUCTION

This chapter briefly discuss on the project background. This chapter also includes problem statement, objective, scope of the project and the thesis outline

1.1 Project background

Material characterization is very essential nowadays since it is mainly focused in numerous applications ranging from designing electronic circuit to satellite applications. Material characterization is mainly about characterizing a material's properties in terms of chemical, mechanical and physical. As for instance, physical characteristic of material incorporate color, dimension, texture and thickness that defines the material physically. Properties that describes how a substance changes into completely different substance are called chemical properties such as flammability, oxidation or corrosion resistance. On other hand, mechanical properties of material are

those properties that involve a reaction to an applied load. The most common mechanical properties are stiffness, ductility, impact resistance and fracture toughness.

The need of material characterization is for determining a particular material's properties to enhance its functionality or properties and also classify them in applications it belongs to. Without characterizing material properly, classifying cannot be performed accurately and this may leads to damage to the material and to the user of the material. Thus, material characterization is important and there are numerous techniques presented such as chemical analysis, ultrasonic characterization, x-ray spectrometry characterization and microwave characterization.

Our main focus of this project is characterization involving free space measurements of solid materials. When it comes to characterizing material in microwave frequency region, the main attention is given to dielectric properties of material. Dielectric properties plays important role in a material because it is providing beneficial details about the storage and dissipation of electric and magnetic in materials and also provides insight into the feasibility of using the material in potential applications.

1.2 Problem Statement

Material characterization is the process of measuring and determining physical, chemical, mechanical and microstructural properties of materials. Through characterization process, able to extract fundamental properties of any type material. It also determines the use of material along with its advantages and deficiency. Adding to that, characterization of materials helps to understand and quantify whether a specific material is suitable to a particular application. Thus, if at all the materials are

not properly characterized and used in an automotive, aerospace or biomedical product can be very dangerous as it has the potential of putting user in danger.

In general, materials can be classified into conductors, semiconductors and insulators or dielectric materials. Hence, dielectric materials plays an important role in our daily life especially every electronic circuit. In most cases, electronic circuits are built using dielectric materials for high frequency operations and performance of the operation is totally depends on the dielectric properties of the material that used to build in. Consequently, there is need to have understanding of the properties of dielectric materials at such operating frequency.

The measurement of dielectric properties at microwave frequency as well as in radio frequency (RF) is very relevant especially in the analysis exploration, such as in biomaterial science, telecommunication field and also microwave circuit design. Ordinarily, the techniques used for the microwave characterization of dielectric materials are classified into different groups which are transmission/ reflection line method, open ended coaxial method, component design approach and free space method.

Most of these techniques are widely used and each techniques has its own constraints along with the frequency at which the measurements can be performed and the type of material that can be measured. Component design approach and free space measurement technique is our main focus in microwave characterization.

Component design approach is concerned to materials for designing such as antennas, absorber and sensor to enhance the performance in its own application. When it comes to component design approach, the process of characterizing the

materials takes a longer time. This is mainly because the material has to be characterized under different technical design parameters. Thus, it also cause a delay in simulation process.

Moreover, component design approach is not universal in where it is not applicable other than its own application because it may not function accurately due to the difference in structure and properties of material. Adding to that, component design approach is considered as the destructive technique that can damage the material. This is because due to characterizing the same material under different technical parameters repetitively.

The drawbacks of component design approach can be overcome with free space transmission-reflection method known as non-destructive technique. In transmission-reflection method, object is the interface between transmitter and receiver. A simple setup is only needed that do not requires expensive equipment for characterizing purpose. Since, this method can be considered more pragmatic approach, we have considered to apply this technique to characterize the dielectric properties of solids.

1.3 Objective

- Design and develop material characterization system based on free space transmission-reflection method to characterize dielectric properties of solids.

1.4 Scope

The scope of project are listed as below:

1. Design and develop a free space transmission-reflection (T/R) measurement system to characterize dielectric properties of solids.

2. System integration deployment of free space transmission-reflection (T/R) measurement system.
3. Testing the developed free space transmission-reflection (T/R) measurement system to characterize dielectric properties of solids

1.5 Thesis outline

This thesis consists of five chapters which are categorized as below:

Chapter 1: Introduction-This chapter introduces and explains the purpose of this project through problem statement, objective and scope of the project.

Chapter 2: Literature Survey- This chapter provides a detailed background of the material characterization and methods used to characterize material properties.

Chapter 3: Methodology- This chapter describes the methods and procedures used to design this project in details as well as flow charts, discussion on selection of method to be used in this project and further details to design the system.

Chapter 4: Result and discussion- This chapter illustrates and analyses the result of this project and discusses the possible further improvements of the developed device.

Chapter 5: Conclusion and recommendation- This chapter presents the conclusion of the project. The strengths and limitation of the project will be highlighted as well. Furthermore, some recommendations for future works will be provided.