COMPAT MULTIPORT REFLECTOMETER FOR MICROWAVE MATERIAL CHARACTERIZATION

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requirements for the award of the degree of
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DEDICATION

Dedicated to my beloved parents who have been a source of strength and inspiration, and who continually provided their moral, emotional and financial support.

And To my supportive and inspirational supervisor for your patience and encouragement throughout my education.

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ABSTRACT

In this project, a simple, innovative, and compact three-probe reflectometer has been developed. The reflectometer can be used to find the complex reflection coefficient of an unknown device under test over a relatively broad frequency range based on the three measured power amplitudes of the three probes. The designed three-probe reflectometer is expected to provide results comparable to those provided by a commercial vector network analyser. Besides simple, the main advantage of this three-probe reflectometer is that it only involves scalar amplitude measurements and no phase-shift measurements, whereby it has less electronic circuit component requirements and reduces the cost of the electronic components, as well as it is insensitive to the operating temperature. The main contribution of this work is that the operating bandwidth of the reflectometer has been improved by optimizing the distance or space position between the three probes along the transmission line. Besides that, a calibration process was designed to eliminate systematic errors of reflectometer.

ABSTRAK

Dalam projek ini, satu reflektor tiga-probe yang mudah, inovatif, dan bersaiz padat telah dibinakan. Reflector tersebut digunakan untuk mencari pekali pantulan refleksi kompleks dalam julat frekuensi yang luas untuk alat yang tidak diketahui berdasarkan tiga ukuran amplitud kuasa. Reflector yang direkakan tersebut dijangka membekalkan prestasi yang setanding dengan penganalisis rangkaian vektor komersial. Selain daripada kemudahannya, kelebihan utama bagi reflector tersebut adalah ia hanya melibatkan pengukuran amplitud skalar dan tiada melibatkan pengukuran tahap fasa, di mana ia hanya memerlukan sedikit komponen litar elektronik, mengurangkan kos komponen elektronik, dan juga tidak sensitif kepada suhu operasi. Sumbangan utama kerja ini adalah lebar jalur operasi reflectometer telah diperbaiki dengan mengoptimumkan jarak atau kedudukan ruang antara tiga probe pada sepanjang talian penghantaran. Selain itu, proses penentukuran direkakan supaya menghapuskan ralat sistematik untuk reflector tersebut.

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LIST OF ABBREVIATIONS

VNA	-	Vector Network Analyzer
DUT	-	Device Under Test
VCO	-	Voltage Controlled Oscillator
LMS	-	Least Mean Square
RLS	-	Recursive Least Square
TLS	-	Total Least Square
TLMS	-	Total Least Mean Square
RF	-	Radio Frequency
BLMS	-	Block Least Mean Square
SLMS	-	Sign Least Mean Square
NLMS	-	Normalized Least Mean Square
MSE	-	Mean Square Error
DC	-	Direct Current

LIST OF SYMBOLS

Γ	-	Reflection Coefficient
$P_n - P_i$	-	Power measured at probe number n or probe i respectively
P_{io}	-	Power measured at probe number n, when the reflectometer is connected to an open load
P_{is}	-	Power measured at probe number n, when the system is connected to a short load
P_{ref}	-	Incident power
θ	-	Angle of the reflection coefficient
$\lvert\Gamma_L\rvert$	-	Magnitude of the reflection coefficient
Γ_{raw}	-	Reflection coefficient before calibration
θ_{raw}	-	Angle of the reflection coefficient before calibration
ΔZ1	-	The phase difference between the first and second probe
ΔZ2	-	The phase difference between the second and third probe

CHAPTER 1

INTRODUCTION

This chapter provides the basic overview of the development of the reflectometer, and the creation of a calibration or error correction algorithm. The applications for which the reflectometer is designed are briefly mentioned. This chapter includes the problem background, problem statement, research goal, research objectives and captions.

1.1 Introduction

Multiport reflectometer is a low-cost passive microwave measurement component that can be use for wide variety of measurements. This research focuses on designing and fabricating a reflectometer to be used is finding material's properties in a process known as material characterization.

1.2 Problem Background

Microwave imaging applications have been witnessing significant demand in the last century. It is common in most research of microwave applications that a Vector network analyzer (VNA) used as a transmitter and a receiver to provide accurate measurements and calculate complex relations between the input and output signals. Vector network analyzers, despite accurate, are still bulky and expensive, making them impractical for many applications. In this research, a portable low-cost multiport reflectometer is designed as an alternative.

Significant interest has been shown in using the multiport reflectometer for application ranging from imaging such as human imaging organs for medical applications to material characterization by correlating the reflection coefficient to material properties. By designing this reflectometer to work over a wide frequency range, its imaging capability can be improved considerably.

To account for imperfections and losses that might occur in the design a suitable calibration process is developed. There are various calibration standards and, in this research, the most prominent ones will be discussed and analyzed. And a suitable calibration method will be developed to work with the designed reflectometer prototype.

By realizing the importance of accurate reflection coefficient calculation, it can contribute an advantage to the industry. Reflection coefficient can be used in material characterization, or driving material properties.

1.3 Problem Statement

Modern automatic network analysers use complex and expensive heterodyne and mixing circuitry to obtain the amplitude and phase of unknown reflection coefficients at microwave frequencies. Traditionally, microwave measurement devices such as a vector network analyser are expensive and limited for laboratory usage. Meanwhile may applications require microwave measurement capability that is low cost and compact in size. Therefore, in this research we analyse the design of a simple fabricable model based on multiport reflectometer for calculating the reflection coefficient for an open-ended coaxial sensor.

Practically, the components of the multiport reflectometer include losses, therefore, error correction method or a calibration method is an essential part of the design process. The least mean square technique is the chosen method of calibration, due to its simplicity and reliability

1.4 Research Goal

The goal of this project simply is developing a testing a method in driving the reflection coefficient of a device under test (DUT). A reflectometer is to designed fabricated and tested, and a calibration method is to be developed to account for errors and losses in the fabricated design.

1.4.1 Research Objectives

In this research, there are three objectives to be met in order to complete the research. The research objectives are as follows:

(a) To investigate the characteristics and operation of the multiport reflectometer as an alternative measurement instrument to the Vector Network Analyzer.

(b) To eliminate imperfect characteristics by implementing a suitable error correction/calibration method

(c) To verify and test the reflectometer and its calibration method with the use of different loads.

1.5 Captions

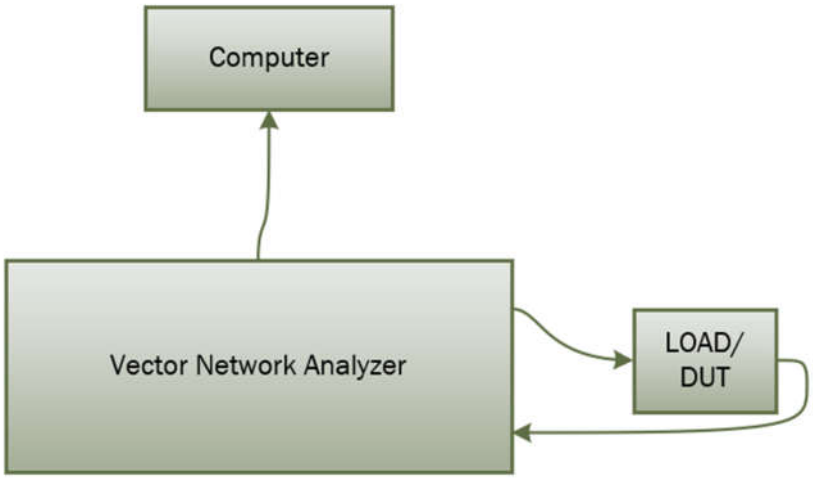

Figure 1-1 Measuring the reflection coefficient of a load using a Vector Network analyser

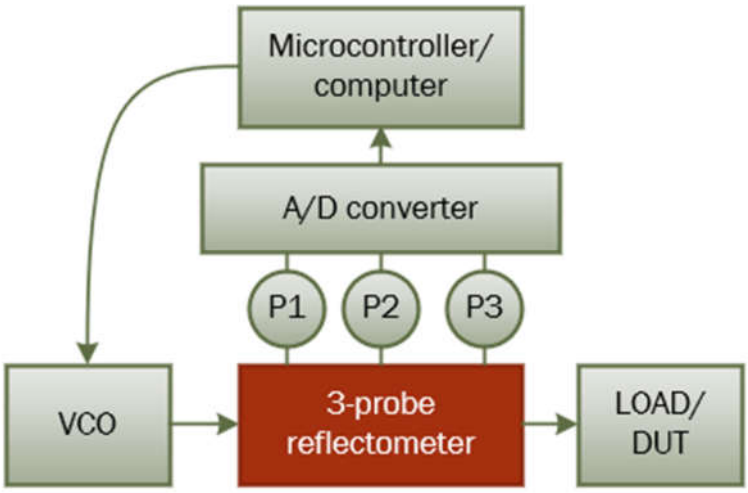

Figure 1-2 Measuring the reflection coefficient of the load using a 3-probe reflectometer

The system proposed consists of

- multiport reflectometer,
- a Voltage controlled oscillator (VCO), as signal source,
- Power detectors, connected at each probe (P1, P2, and P3),

- An analog to digital convertor (A/D Converter) to convert the signal coming from the power detectors.
- a load or a device under test (DUT)
- a microcontroller or Computer for calculating the reflection coefficient.

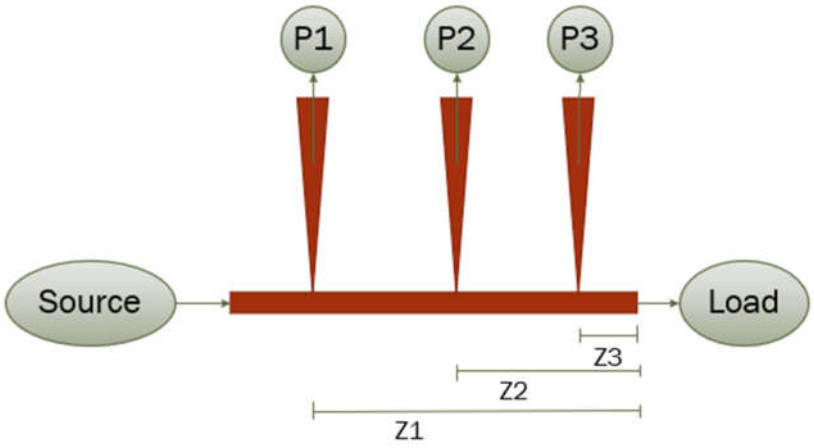

Figure 1-3 A more detailed representation of a 3 port microstrip reflectometer

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LIST OF PUBLICATIONS

ObaidAllah Elshafiey and You Kok Yeow "Compact Multiport Reflectometer for Microwave Material Characterization" *2019 IEEE 14th Malaysia International Conference on Communication (MICC)*. IEEE, 2019. (Accepted)