A FREE-SPACE MEASUREMENT OF COMPLEX PERMITTIVITY OF NATURAL RUBBER FILLED WITH CARBON BLACK AT MICROWAVE FREQUENCY

MOHD ILHAM BIN ADAM
FACULTY OF ELECTRICAL ENGINEERING
UNIVERSITI TEKNOLOGI MARA
40450 SHAH ALAM
SELANGOR DARUL EHSAN

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ABSTRACT

This project involves a free-space measurement system operating in the 7.5 - 12.5 GHz (X-band) frequency range to measure the Reflection and Transmission Coefficients, S_{11} and S_{21}, of the planar samples. It involves measurements of the Dielectric Constant of the Natural Rubber which filled with different concentration of Carbon Black (HAF N330). To eliminate the effect of Teflon, FORTRAN 77 computer program is used and the Complex Electric Permittivity is calculated from the measured values of the Reflection Coefficient, S_{11} and the Transmission Coefficient, S_{21} using Borland C++ computer program. Another method, the Complex Electric Permittivity is calculated from the measured values of the Transmission Coefficient, S_{21} only using FORTRAN 77 computer program.

The measurement system consists of transmit and receive horn lens antennas, a vector network analyzer, computer and a printer. Diffraction effects at the edges of the samples are minimized by using spot- focusing lens antennas. Errors due to multiple reflections between antennas via the surface of the samples are corrected by using a free-space LRL (line, reflect, line) calibration technique. For flexible samples, the sample had to be sandwiched between two quarter-wavelength (at mid band) Teflon plates, to eliminate the effect of sagging. Because of the far-field focusing ability of horn lens antennas, free-space measurement can be made at microwave frequency in a relatively compact and simple measurement setup.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The measurement of complex permittivity of materials at microwave frequencies can be performed in many ways. Waveguide methods are popular, where the sample is precisely machined to fit inside the waveguide. Rectangular and coaxial waveguides are used, rectangular samples are easier to produce than coaxial ones, and however they can only be used over a limited frequency range. Coaxial waveguide allows extremely wide-band measurements but sample preparation is difficult. A vector network analyzer is generally used to collect the reflected and transmitted signals, and permittivity value can be extracted from the results.

Waveguide measurements suffer from errors caused by incomplete filling of the waveguide by the sample. Corrections for this have been proposed with some success but are not perfect. Sample preparation is destructive and often time consuming. Some materials are not suitable for waveguide measurements, such as those containing long fibers, or foams with large voids. High frequency measurements are especially difficult due to waveguide size. Free space techniques overcome many of these problems.

The main objective of this project is to develop a free space measurement system at microwave frequencies in the frequency range of 7.5 GHz to 12.5 GHz (X-band) for measured a Reflection Coefficient, S_{11} and a Transmission Coefficient, S_{21} of the Natural Rubber filled with different concentration of Carbon Black (HAF N330). The Complex Permittivity (ε^*) is calculated from the measured values of S_{11} and S_{21}.

A Free-space microwave measurement (FSMM) method is non-destructive and contactless; hence, it is suitable for measurements of the complex electric permittivity of the rubber composites under high-temperature conditions. In