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JOHOR BAHRU

SEEL 3742

BASIC MICROWAVE LABORATORY

Dielectric Measurements for Liquids

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Title **Dielectric Measurements for Liquids**

Background Accurate dielectric measurement data is increasingly vital across industries due to advancements in complex technologies. In the automotive sector, precise data is crucial for developing high-capacity batteries and robust capacitors. The food industry relies on accurate measurements for quality assurance in advanced food-processing techniques. In medicine, determining dielectric parameters is essential for optimizing medical devices using electromagnetic stimulation. Antenna and microwave circuit performance hinges on substrate material parameters, and obtaining precise material data during development significantly reduces design time. Despite the importance of this data, current measurement equipment for dielectric properties often proves cumbersome and yields imprecise results.

Objective Determinate the dielectric properties of liquids at microwave frequencies using open-ended coaxial probe.

Task Using the available instruments or tools in the Basic Microwave laboratory in order to set up an experiment to measure the dielectric properties of a liquids.

In this work, the dielectric properties of three well-known liquids, namely propan-1-ol, ethanol, and methanol, are tested.

Instruments

(a) FieldFox Handheld Microwave Analyzer

(b) Coaxial cable

(c) 85052D Calibration kits

(d) Modified SMA connector

(e) 50 ml methanol, 50 ml ethanol and 50 ml propan-1-ol

Brief Measurement and Data Analysis Guidelines

1 Connect the coaxial cable to port-1of FieldFox microwave analyzer.

2 Calibrate the end of the coaxial cable using calibration kits.

3 Connect the SMA connector to the end of the cable.

4 Measure the complex reflection coefficient, S_{11}^{*} of air, Teflon, and water from 1 GHz to 5 GHz, respectively.

5 Measure the complex reflection coefficient, S_{11}^{*} of the propan-1-ol, ethanol, and methanol from 1 GHz to 5 GHz, respectively.

6 The relative complex permittivity, ε_r of the test liquids can be found as:

$$\varepsilon_r = -\left(\frac{\Delta_{m\_a}\Delta_{w\_t}\varepsilon_{Water}\varepsilon_{Teflon} + \Delta_{m\_t}\Delta_{a\_w}\varepsilon_{Air}\varepsilon_{Water} + \Delta_{m\_w}\Delta_{t\_a}\varepsilon_{Teflon}\varepsilon_{Air}}{\Delta_{m\_a}\Delta_{w\_t}\varepsilon_{Air} + \Delta_{m\_t}\Delta_{a\_w}\varepsilon_{Teflon} + \Delta_{m\_w}\Delta_{t\_a}\varepsilon_{Water}} \right) \quad (1)$$
$$= \varepsilon_r' - j\varepsilon_r''$$

The parameters in equation (1) are given as:

$\Delta_{m\_a} = S_{11\_\text{Liquid}}^{*} - S_{11\_\text{Air}}^{*}$, $\Delta_{m\_t} = S_{11\_\text{Liquid}}^{*} - S_{11\_\text{Teflon}}^{*}$,

$\Delta_{m\_w} = S_{11\_\text{Liquid}}^{*} - S_{11\_\text{water}}^{*}$, $\Delta_{a\_w} = S_{11\_\text{Air}}^{*} - S_{11\_\text{Water}}^{*}$,

$\Delta_{t\_a} = S_{11\_\text{Teflon}}^{*} - S_{11\_\text{Air}}^{*}$, $\Delta_{w\_t} = S_{11\_\text{Water}}^{*} - S_{11\_\text{Teflon}}^{*}$

where $S_{11\_\text{Air}}^{*}$, $S_{11\_\text{Teflon}}^{*}$, and $S_{11\_\text{Water}}^{*}$ are the measured complex reflection coefficients for air, Teflon, and water, respectively. The relative complex permittivity, ε_{Air} of air is a constant value equal to $1.0006 - j\,0$. On the other hand, the ε_{Teflon} of Teflon is $2.03 - j$ 0.0004. The relative complex permittivity, ε_{water} of water in equation (2) is calculated from Cole-Cole model as:

$$\varepsilon_{Water} = 4.22 + \frac{78.6 - 4.22}{1 + \left[j2\pi f \left(8.8\times10^{-12} \right) \right]^{1-0.013}} \quad (2)$$

It should be noted that $S_{11\_\text{Liquid}}^{*}$ is either $S_{11\_\text{Propanol}}^{*}$ or $S_{11\_\text{Ethanol}}^{*}$ or $S_{11\_\text{Methanol}}^{*}$ (Based on which liquid you are measuring).

Weekly Schedule

Week 1 Measure the complex reflection coefficient, S_{11}^{*} of air, Teflon, and water from 1 GHz to 5 GHz, respectively.

Measure the complex reflection coefficient, S_{11}^{*} of the propan-1-ol, ethanol, and methanol from 1 GHz to 5 GHz, respectively.

Manage the measured complex reflection coefficient, S_{11}^{*} data

Week 2 Convert the dielectric constant, ε_r' and loss factor, ε_r'' for the liquids from the complex reflection coefficient, S_{11}^{*} data using equation (1).

Compare the converted values of ε_r' and ε_r'' with the ideal values from Cole-Cole model in equation (2).

$$\varepsilon_r = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + \left(j2\pi f \tau\right)^{1-\alpha}} \tag{2}$$

where symbol f is the operation frequency (in Hertz). The Cole-Cole model's parameters at room temperature for:

Propan-1-ol: $\varepsilon_s = 20.44$, $\varepsilon_\infty = 3.8$, $\tau = 320.685 \times 10^{-12}$ s and $\alpha = 0$.

Ethanol: $\varepsilon_s = 24.5$, $\varepsilon_\infty = 4.52$, $\tau = 160.442 \times 10^{-12}$ s and $\alpha = 0$.

Methanol: $\varepsilon_s = 33.7$, $\varepsilon_\infty = 4.45$, $\tau = 4.95 \times 10^{-11}$ s and $\alpha = 0.036$.

Week 3 Discuss and analysis of the measurement data.

Complete the writing report.