

**UNIVERSITI TEKNOLOGI MARA**

**NONDESTRUCTIVE AND NONCONTACT  
DIELECTRIC MEASUREMENT METHODS FOR  
LOW-LOSS AND HIGH-LOSS LIQUIDS USING FREE  
SPACE MICROWAVE MEASUREMENT SYSTEM IN  
8-12.5 GHz FREQUENCY RANGE**

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## ABSTRACT

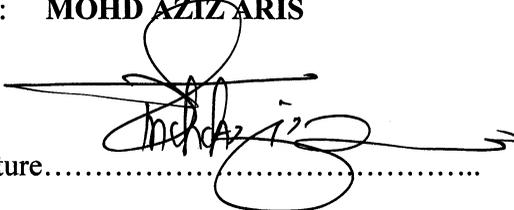
Knowledge of wideband dielectric properties of liquid materials is necessary in many applications such as biomedical, remote sensing, powder technology and radar absorbing materials. Nondestructive, noncontact, in situ and real time measurement of dielectric properties of liquids is important for evaluation of complex material systems such as service-aged transformer oil. Free-space microwave measurement (FSMM) system (which is nondestructive and noncontact) was developed for accurate measurement of dielectric properties of low-loss and high-loss liquids at microwave frequencies. Three free-space methods were used, namely, reflection and transmission method, transmission only method and metal-back method. These methods were especially developed and tested for dielectric measurement of liquids in free-space. This is the first reported implementation of transmissions only and metal-back methods in free-space for low-loss liquids at microwave frequencies. FSMM system consists of spot focusing of horn lens antennas, mode transitions, coaxial cables and vector network analyzer (VNA). All measurements were made using FSMM system in the frequency range of 8 GHz to 12 GHz and temperature fixed at  $20^{\circ}\text{C}$ . Inaccuracies due to diffraction from the sample are minimized by using spot focusing horn lens antennas. Errors due to multiple reflections between antennas were minimized by using free-space LRL (line, reflect, line) calibration technique and time domain gating (a feature of VNA). The liquid is contained in a container consisting of two Plexiglas plates with known dielectric properties. These Plexiglas plates are designed to be quarter wavelength at mid band to reduce reflectivity of the liquid sample. The effect of Plexiglas plates is removed from the knowledge of dielectric properties of Plexiglas and thickness of plates. Dielectric properties of low-loss liquids such as Dioxane, Benzene and transformer oil are measured using reflection and transmission, transmission only and metal-back methods. High-loss liquids such as Methanol, Ethanol, Ethylene Glycol and N-Propyl Alcohol, dielectric constants and loss factors were measured using reflection and transmission, transmission only and metal-back methods. It was found that reflection and transmission method gives accurate results for high-loss liquids. Transmission only and metal-back methods give accurate results for low-loss liquids. Values of dielectric constant for low-loss liquids are almost constant in the frequency variation. Whereas, dielectric constant of high-loss liquids are reduce in magnitude if frequency increased. Results for all liquids are compared with published data. For high-loss liquids, our experimental results are also compared with data calculated from previously published Debye parameters. All results for dielectric constants and loss factors for all samples have close match with published data. The percentage error for dielectric constant is  $\pm 3.9\%$  and for loss tangent is  $\pm 0.008$  in magnitude for metal-back method. The transmission only method gives an error of  $3.83\%$  for dielectric constant and  $\pm 0.02$  for loss tangent. The percentage error for dielectric constant is  $\pm 2.9\%$  and error for loss tangent is  $\pm 0.025$  in magnitude for reflection and transmission method. These errors in dielectric properties are due to error in measurement of S- parameters using FSMM system. These errors in S-parameter measurements are due to post-calibration systematical, random and drift errors.

## Candidate's Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the result of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any academic institution or non-academic institution for any other degree or qualification.

In the event that my thesis be found to violate the conditions mentioned above, I voluntarily waive the right of conferment of my degree and be subjected to the disciplinary rules and regulations of Universiti Teknologi MARA.

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Candidate's Signature.....

Date: 21<sup>ST</sup>. OCTOBER 2005

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