

**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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**Thesis submitted in fulfillment of the requirements for the degree of  
Master of Science**

**Faculty of Electrical Engineering**

**September 2005**

## ABSTRACT

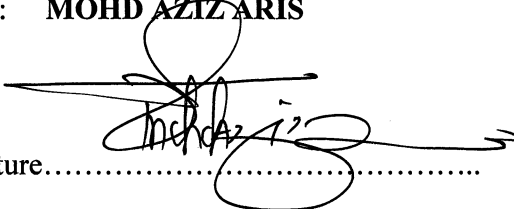
Knowledge of wideband dielectric properties of liquid materials is necessary in many applications such as biomedical, remote sensing, powder technology and radar absorbing materials. Nondestructive, noncontact, in situ and real time measurement of dielectric properties of liquids is important for evaluation 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

## ACKNOWLEDGEMENTS

In the name of Allah S.W.T. the most Merciful and the Most Compassionate

I would like to extend my deepest gratitude and many thanks to my advisor, Assoc. Prof Dr. Deepak Kumar Ghodgaonkar for all of his guidance and support throughout the work of this project. I have a very deep respect for Assoc. Prof Dr. Deepak Kumar as a supervisor and as a friend. His insights, wealth of knowledge, and sense of humor have been both an inspiration and a guiding light throughout this thesis. He is truly a brilliant man, and it has been an honour and privilege working with him.

I would like to extend sincere appreciation to Assoc. Prof. Norasimah Khadri as co-supervisor. It has been an honour working with her. I would also like to thank Assoc. Prof. Dr. Zaiki Awang, head of the Microwave Technology Centre (MTC) department for reading and commenting on my research and for his permission to use MTC's laboratory. Also thanks to all administrative and technical staff of MTC and Faculty of Electrical Laboratory, Mr. Hisham Mahamad Mrs. Nuraida Jamil, Mr. Khalim and Mr. Azman.

I would also like to extend special thanks to Mr. Mazlan, Mr. Rahim Hassan and Mr. Zamran from TNB Research for providing a vast amount of transformer oil to be analyzed. Deep gratitude is also extended to all the staff of IPSIS University Technology MARA, Faculty of Electrical Engineering University Technology MARA, Mrs. Norhasimah Baba for her guidance and to all my friends for their support, praise, and sense of humor.

It is difficult to explain how grateful I am to the two people who have been there for me literally since the first day of my birth. My parents, Mr. Aris Saniman and Mrs. Sabtariah Tampakan, are truly incredible people and I am extremely thankful for everything they have ever done for me. They have always believed in sacrificing everything so that I may pursue the best education possible, and they are truly superb role models. I owe every success to their guidance and support and I can only say that I will be forever grateful.

My sincere gratitude to Almighty Allah S.W.T for his guidance that made the completion of the thesis achievable.

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