

**UNIVERSITI TEKNOLOGI MARA**

**DETERMINATION OF MOISTURE CONTENT  
AND GRAIN ANGLE OF MALAYSIAN WOOD  
SPECIES USING THE MICROWAVE  
TRANSMISSION TECHNIQUE IN THE  
FREQUENCY RANGE OF 8 TO 12 GHz**

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Thesis submitted in fulfillment of the requirements

for the degree of

**Doctor of Philosophy**

**Faculty of Civil Engineering**

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## **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 the original and the result of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other 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 agree to be subjected to the disciplinary rules and regulations of Universiti Teknologi MARA.

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## Abstract

Microwave Non-Destructive Testing (MNDT) are fast, contact-less, accurate and continuous techniques for the evaluation of physical properties of wood such as moisture content, slope-of-grain and density using microwave. The Free Space Microwave Measurement (FSMM) system has been developed for this purpose. The system consists of a pair of spot-focusing horn lens antennas mounted on a table connected to the two ports of Wiltron37269B Vector Network Analyzer (VNA) using precision coaxial cables, rectangular-to-circular and coaxial-to-rectangular waveguide adapters. A calibration and optimization procedure was performed to the FSMM system before using it. Microwave at the frequency range of 8 to 12GHz was propagated through the wood specimen placed between two antennas and the reflection coefficient ( $S_{11}$ ) and transmission coefficient ( $S_{21}$ ) was measured. In this research, the  $S_{21}$  coefficient has been used to measure the permittivity of wood. The permittivity of wood comprises of two components, the dielectric constant ( $\epsilon'$ ) and loss factor ( $\epsilon''$ ). Since wood is an anisotropic material, therefore  $\epsilon'$  and  $\epsilon''$  of the wood varies when measured at different angles to the wood grain. A data base of  $\epsilon'$  and  $\epsilon''$  of twenty-five Malaysian wood species, measured at  $0^\circ$  (parallel),  $30^\circ$ ,  $60^\circ$  and  $90^\circ$  (perpendicular) to wood grain has been developed for future use. All measurements were made in the laboratory at temperatures of between  $25 \pm 2^\circ\text{C}$  was undertaken. A study on measuring the moisture content and wood grain angle using the FSMM system of three wood species specimen of Kempas (*Koompassia malaccensis*), Yellow Meranti (*Shorea spp*) and Petai (*Parkia spp*) was undertaken. The measurement of wood grain angle only was carried on Medang specie (*Specie of Lauraceae*) was carried out. The wood specimen  $\epsilon'$  and  $\epsilon''$  were measured at several moisture content levels from saturated to oven-dry states at an angle from  $0^\circ$  to  $90^\circ$  to the wood grain. The measured  $\epsilon'$  was then used to calculate the wood's moisture content based on several new models adopted from the Mixture Theory and Theory of Grain Angle measurement. The study shows that the measured  $\epsilon'$  and moisture content is dependent on wood grain angle and density and microwave's frequency. A new method known as Averaging Angle method has been developed. This method eliminates the need to determine the wood grain angle prior to measuring the moisture content using microwave. The moisture content measured based on the new method have been compared with the moisture content measured using the conventional Oven-dry method. Results from regression analysis carried out shows close relationships between the moisture content measured using the MNDT method and Oven-dry method. A statistical t-test analysis has been conducted to validate the significant difference of the results obtained from both methods at 95 percent level-of-confidence. Therefore, the new MNDT technique using the FSMM system, as is clear from the results is accurate, non-destructive, contact-less measures moisture content of wood with minimum time and effort, and does not requires prior knowledge about the grain direction of wood. The second significant contribution of the research is the application of the new technique of determining moisture content using a new simplified, user friendly and advance technique that can minimize moisture related problem encountered in the manufacturing process and in structural and commercial use of wood and timber.

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