AN INITIAL STUDY TO INVESTIGATE THE POTENTIAL OF MICROWAVE TOMOGRAPHY FOR AGARWOOD IMAGING

Thomas Tan Wan Kiat, Mohd Hafiz Fazalul Rahiman, Soh Ping Jack

ABSTRACT

Microwave tomography has indicated potential for non-invasive assessment of agricultural product. It has been selected to inspect resin-containing trees. Such trees include Aquilaria tree which consists of dark resinous heartwood in the tree trunk. The resin is called agarwood which is sweet-smelling possesses a huge economical potential. However, it is hard to validate a resin containing Aquilaria tree. The aim of this paper is to demonstrate that simulation can generate satisfactory results in proving the feasibility of microwave tomography in diagnosing the the content of an Aquilaria tree trunk. A waveguide-based simulation is setup with an operating frequency of 1 GHz. Eight waveguides surround the sample under test (SUT), with a diameter of at least 15cm. The size and shape of the agarwood is extracted from the captured image based on a contour tracing algorithm. It is then imported in the simulation software to create the geometry of the agarwood. Waveguide and SUT are modelled by a 2D model contingent on the finite element method (FEM). The model will result in a moderate computation effort for collecting the electromagnetic behaviour for image reconstruction. In summary, the obtained result can used as a reference to optimize the microwave tomography system.

Keywords: Aquilaria tree, Agarwood, Microwave tomography

Introduction

Agarwood is the fragrant resin-infused wood obtained from the wounded trees of Aquilaria species (Liu et al., 2013). It is cultivated by a number Southeast Asian Country including Indonesia, Malaysia, Vietnam, Cambodia, Thailand, Laos and Papua New Guinea, with Singapore being the main trade centre. The precious, expensive and fragrant agarwood has been applied for centuries as incense in Buddhist, Hindu and Islamic ceremonies (Liu et al., 2013). It also plays an significant part in Chinese Traditional Medicine as a sedative and carminative, and to relieve gastric problems, coughs, rheumatism and high fever (Liu et al., 2013). The essential oil is a highly in demand as an ingredient in deluxe perfumery for its warm, unique balsamic notes with sandalwood-ambergris tonalities (Liu et al., 2013). Beside the large existing demand for agarwood in the market, a method to ensure the quality of this crop is significant in guaranteeing customer satisfaction.

Currently, cutting down trees is the solution to obtain agarwood. This act cannot guarantee the quantity of agarwood obtained precisely and constantly. It takes times to wait for the tree to grow. Furthermore, human experience cannot ensure the location and quantity of agarwood in the tree. So, microwave tomography is selected to overcome this uncertainty. Microwave tomography is a non-ionizing imaging technique that provides a quantitative image of the dielectric profile of an object (Mojabi, Ostadrahimi, Shafai, & LoVetri, 2012). It is capable to be used in agriculture due to it is relative insensitivity to environmental conditions. Dust and water vapour do not affect the microwave measurements in comparison to light-based techniques such as infrared (Kraszewski & Nelson, 1995). Besides, such technique also does not alter or contaminate the material under test. It enables quick, non-destructive and continuous monitoring on the test samples, (Rahiman, Kiat, Jack, & Rahim, 2015).

Thus, this paper demonstrates the assessment of the microwave tomography in imaging agarwood by means of simulations to estimate the location of agarwood in the Aquilaria tree. The setup and methodology will be first explained, prior to the presentation of the gathered images. A discussion on the obtain images will also be discussed, prior to our concluding remarks.

FORWARD PROBLEM

A common schematic of a microwave tomography system is shown in Figure 1. The unidentified object of interest (OI) is positioned inside an imaging domain, D. The OI is illuminated consecutively by transmitters, TX, from different angles. Meanwhile, the receivers, RX, collect the scattered field in a data region, S, outside the OI for each angle of illumination (Ostadrhahimi, 2011). Each illumination involve an electromagnetic wave emitted from the transmitter (Kundu et al., 2010).

![Figure 1: Schematic of a conventional microwave tomography system](image-url)
Incident electric field, $E^{inc}$, is the fields in the absence of the OI and the total electric field, $E^{tot}$, is the fields in the presence of the OI. The scattered electric field, $E^s$, is the difference between $E^{tot}$ and $E^{inc}$.

$$E^{scat}(r) = E^{tot}(r) - E^{inc}(r) \tag{1}$$

**SIMULATION**

In the present work, a non-invasive way of detecting agarwood among the Aquilaria trees is proposed. Simulation has to be done to obtain reference for the work. Model is being built through simulation software and the profile of the object is obtained by employing MATLAB® in this work.

**SIMULATION SETUP**

In this research, the wood’s diameter of 200mm is generated within the simulation. The wood’s cross sectional diameter was determined according to the work done by Indahsuary et al. (2014) and Karlinasari (2016). Therefore, eight waveguides are set up around the model at a distance of 105mm from the centroid by allowing an extra tolerance of 5% for the wood to fit in. The width of each antenna is 60mm. This configuration is shown in Figure 2. Three images generated with the coordinates representing the shapes of the agarwoods are obtained and sampled from the study done by Liu et al. (2013). These images are used to test the robustness of the system in detection of agarwood. The shape features are extracted using contour tracing algorithm (Seo et al., 2016). The coordinates representing the shapes of agarwood are then imported into the simulation software.

The microwave frequency selected for the simulation is 1GHz. This arrangement is made because normally, there are moisture content in the wood. The presence of water will result in an increase in the microwave attenuation as the selected microwave frequency increases (Kiat et al., 2015; Mallach et al., 2016). Hence, the minimal measurement frequency has been selected. The frequency, wood and agarwood properties are stated in Table 1. The relative permeability for both wood and agarwood are 1 because they are not metal. The relative permittivity of wood is taken from (G. I. Torgovnikov, 1993) and the relative permittivity of agarwood resin is taken from (Ueda et al., 1998). The electrical conductivity of wood and resin are calculated based on equation (2) where $\tan \delta$ is the tangent loss, $\omega$ is the angular frequency, $\varepsilon_0$ is the permittivity in free space and $\varepsilon_r$ is the relative permittivity.

$$\tan \delta = \frac{\sigma}{\omega \varepsilon_0 \varepsilon_r} \tag{2}$$

*Figure 2: A 2D model of proposed system*
### Table 1: Electrical properties of wood and agarwood at 1 GHz

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Wood</th>
<th>Agarwood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dielectric loss</td>
<td>Relative permittivity</td>
</tr>
<tr>
<td>1</td>
<td>0.34</td>
<td>6.8</td>
</tr>
</tbody>
</table>

The setup shown in Figure 2 is simulated for three different shapes of agarwood. The final image, $S_{\text{final}}$, is reconstructed based on the equation (3).

$$S_{\text{final}} = \sum_{i}^{N} \sum_{j}^{M} S_{\text{homo}}(i,j,Tx,Rx) - S_{\text{inhomo}}(i,j,Rx,Tx)$$  \hspace{1cm} (3)

where

- $S_{\text{homo}}(i,j,Tx,Rx)$ = simulated image of wood without agarwood
- $S_{\text{inhomo}}(i,j,Tx,Rx)$ = simulated image of wood without agarwood

**RESULT AND DISCUSSION**

In current work, the electric field is seen in the $z$ plane. Figure 3 shows the field drops drastically when it reached the furthest point from the transmitter due to reflection and absorption by the medium. The reconstructed images for three different shapes of agarwood are shown in Figure 4, Figure 5 and Figure 6. The actual image is the real image of a cross-section of Aquilaria tree which is then remodel it using simulation software which is named as original image. The tree trunk is assumed as circular shape to ease the simulation work. By using equation 3, reconstructed image is produced. From Figure 4, Figure 5 and Figure 6, this technique can be used to estimate the presence of agarwood. However, the estimation is not done well. It may be due to the high lost of energy and in the wood and relative permittivity of wood. The reconstructed electric field profiles in Figure 3, Figure 4 and Figure 5 had proved microwave tomography is able to examine the agarwood in the Aquilaria trees which before that the inspection has been done by chopping down the trees and based on human experience to justify it.

![Figure 3: Electric field with frequency for wood without resin](image-url)
Figure 4: Shape 1

<table>
<thead>
<tr>
<th>Shape 1</th>
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<tbody>
<tr>
<td>Actual Image</td>
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<tr>
<td>Original Image</td>
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Figure 5: Shape 2

<table>
<thead>
<tr>
<th>Shape 2</th>
<th>Actual Image</th>
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<tr>
<td></td>
<td>Original Image</td>
</tr>
<tr>
<td></td>
<td>Reconstructed Image</td>
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</table>
CONCLUSION
The study showed the design of eight waveguides microwave tomography system using simulation approach is able to inspect the agarwood in an Aqularia tree at 1 GHz. It is able to identify the location of the agarwood. Yet, the estimation of the agarwood is not done well may be due to the frequency of the microwave and the image reconstruction algorithm. In future work, suitable higher frequency will be selected but nevertheless when the frequency getting higher the equipment becomes expensive and the microwave will scattered. The reconstructed image will have many artefacts. Therefore, it can be improved by refining the algorithm to reconstruct the image of the agarwood in the tree.

REFERENCES


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