Microwave Sensing of Maple Trees for Pest Detection

Kassi Stein and Carey M. Rappaport

Work supported by Gordon - CENSSIS and Northeastern University, Boston, MA 02115 (stein.kas@husky.neu.edu)

Introduction: Problem Identification

The Asian Longhorned Beetle is a pest that poses a current threat to hardwood tree species, particularly maples:
- Their larvae ultimately kill these trees by eating away at the wood, leaving large air voids that interrupt the flow of food and water through the trunk. They tend to infect an entire area at once.
- They leave no visible evidence of infestation, and tree symptoms themselves generally do not appear until it is too late to treat and heal the damage.

Microwave sensing offers a potential means of detecting these beetles.

![Image](https://example.com/image1.png)

![Image](https://example.com/image2.png)

Experiment Configuration

Various configurations of point sources were used to study the effects of each:
- A 20 point sources evenly spaced arranged close to the surface of the bark
- 20 point sources evenly spaced at a radial distance of approximately 15 cm from the bark
- The above arrangement with alternative sign excitations

A rubber ring about 10 cm thick was wrapped around the tree to lessen the air/bark mismatch and improve results. Point sources were placed within the ring with rough bark, and those in the ring with rough bark.

![Image](https://example.com/image3.png)

![Image](https://example.com/image4.png)

Table 1: Values of the dielectric constant and loss tangent at 915 MHz and 25°C assigned to the specific regions of the tree, based on moisture content [2] and wood density [3].

<table>
<thead>
<tr>
<th>Region</th>
<th>Real Dielectric Constant</th>
<th>Imag Dielectric Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Heartwood</td>
<td>11.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Sapwood</td>
<td>11.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Heartwood</td>
<td>11.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Loss Tangent</td>
<td>0.16</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Results

- Typical clutter response due to bark roughness without the rubber ring was found to be less than or equal to 0.02 (Fig. 4).
- Voids as deep as 20 cm could be faintly detected, but only if they were parallel to the bark circumference (Fig. 4(b) and 4(c)). Non-circumferential holes could be faintly detected as deep as 10 cm (Fig. 4(d)).
- Voids close to the surface produced the strongest response.

![Image](https://example.com/image5.png)

![Image](https://example.com/image6.png)

Conclusions

This work demonstrates that it is possible to detect air holes caused by pest damage in maple trees. For pest detection, it is not necessary to reconstruct the damage pattern, just unambiguously sense its effect. Voids closer to the surface consistently produced a stronger scattered field response, though voids as deep as 20 cm could be detected as long as they were parallel to the bark circumference.

Adding a rubber ring around the tree improved detection and decreased the bark clutter threshold.

Research to Reality

Microwaves present a non-invasive solution to detecting damaging holes inside trees affected by Asian Longhorned Beetle infestations. They are safe, so they would not further damage the trees in question.

The addition of a rubber ring decreased the bark clutter response from 0.02 to 0.0165. This held true in both circular and irregular tree geometries. Adding a rubber ring around the tree improved detection and decreased the bark clutter threshold.

![Image](https://example.com/image7.png)

![Image](https://example.com/image8.png)

References


Center Strategy and Legacy

This project incorporates the first thrust level: it is a basic research project (Level 1), with elements of fundamental electromagnetic modeling (FDFD).