COATL-RADAR

Assessing the Quality of Coffee Beans

Chris Kane-Pardy | Henry Sanders | Kamal Smith | Wallace McKenzie

Portland State UNIVERSITY
Maseeh College of Engineering and Computer Science

COATL
COffee And Telesensing Lab

OBJECTIVE

Our objective was to develop a non-destructive radar sensing system to classify coffee beans by their internal moisture content, a key factor in coffee quality, stability, and roasting. To prove viability in comparison to conventional slow, destructive, and inconsistent methods, our goals were:

- Differentiate coffees with moisture levels (e.g., 8%, 10%, 12%)
- Detect an empty sample holder

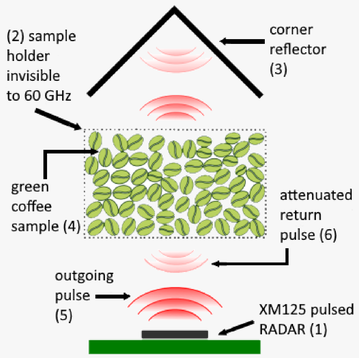

Figure 1: *Conceptual model of material sensing with 60 GHz RADAR for coffee*

APPROACH & INITIAL DESIGNS

3D Printing Phase

Rotating PETG container for beans.

- Stepper motor caused signal noise.
  → Switched to manual rotation.
- Layer inconsistencies introduced interference.
  → Added copper shielding.
- Shielding helped, but the base still distorted readings.
  → Reworked design.

Figure 2: *Stepper motor design*

Aluminum Funnel & Pipe Transition

Fabricated a 1.5" diameter aluminum tube and corner reflector.

- Inconsistent I/Q data forced a shift from permittivity-based to amplitude-only analysis.
  → Introduced multi-scan averaging & shaking to mitigate position-based inconsistencies.
  → Standardized bean samples by weight for moisture % consistency.

Figure 3: *1.5" diameter aluminum tube design*

Wavelength Challenges & Redesign

- 5mm wavelength matched the average characteristic dimension of the bean, causing overlap in amplitudes.
  → Swapped to 8mm tube.
- Caused excessive attenuation.
  → Transitioned to 3/8" diameter.

Figure 4: *8mm diameter aluminum tube design*

RESULTS

Experimental Setup

- **Radar:** Acconeer XM125, 60 GHz PCR.
- **Structure:** 3/8" diameter aluminum tube, corner reflector, and 3D-printed tube holder.
- **Data:** Over **330,000** samples from three green bean varieties with moisture levels of 7.8%, 9.7%, and 11.4%.
- Each input contained **50 real** and **50 imaginary** averaged amplitude values.

Figure 5: *3/8" diameter aluminum tube design*

Model Performance

- **Neural Network:** 5 hidden layers (256 to 16 neurons).
- **Training Accuracy:** ∼95%
- **Live Testing Accuracy:** ∼33%, Class predictions skewed toward the highest-moisture sample.

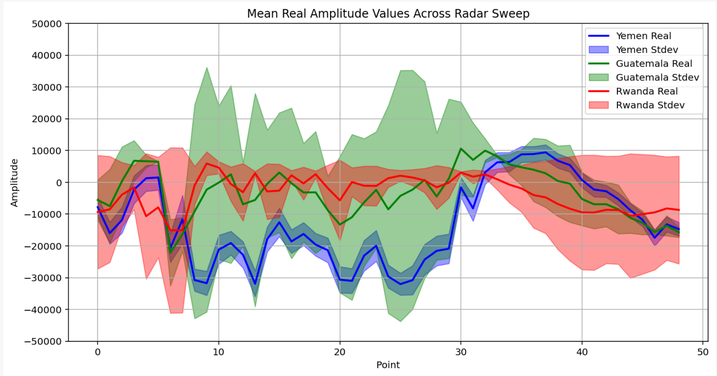

Figure 6: *Mean Real Amplitude Comparison (Aluminum)*

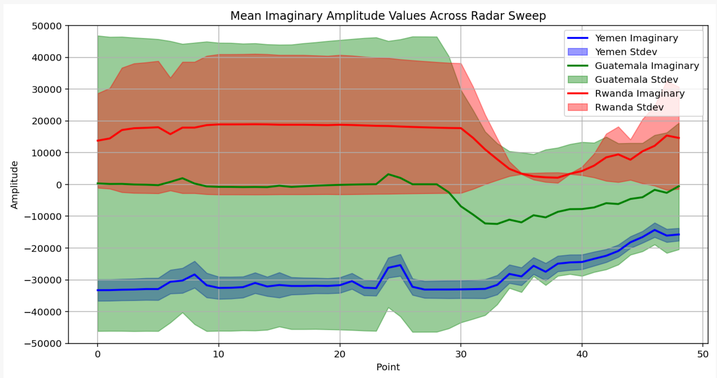

Figure 7: *Mean Imaginary Amplitude Comparison (Aluminum)*

We believe these results are indicative of Mie and Rayleigh scattering, where complex, angle-dependent scattering patterns are produced with significant interference effects. Mie scattering typically occurs when particles are comparable to or larger than the wavelength, and Rayleigh scattering occurs when ϵ_r values are high. In our case, both our wavelength and a coffee bean's characteristic dimension are 5mm, making Mie scattering dominant. We believe the aluminum enclosure amplified these effects. To mitigate them, we transitioned to an open-air test setup.

RESULTS CONT.

Experimental Setup

- **Structure:** Open-air radar holder, 3D printed bean holder, trihedral corner reflector
- **Data:** Comparison between unroasted green beans and various levels of roasted beans
- Each input contained **50 real** and **50 imaginary** averaged amplitude values.

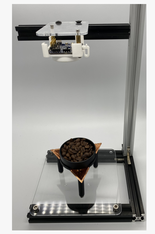

Figure 8: *Open-air design*

Unroasted Beans

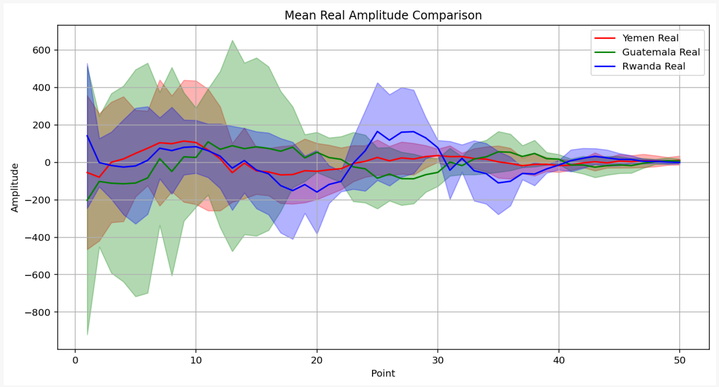

Figure 9: *Mean Real Amplitude Comparison (Open-air)*

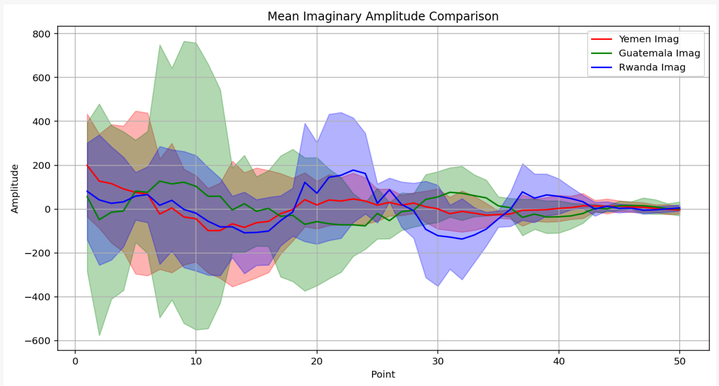

Figure 10: *Mean Imaginary Amplitude Comparison (Open-air)*

Roasted Beans

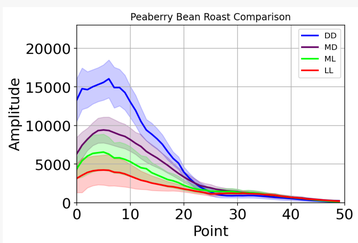

Figure 11: *Roasted Peaberry Bean Comparison*

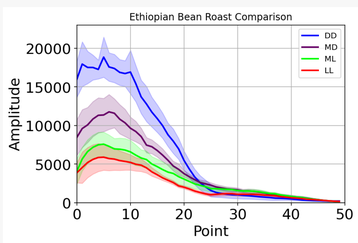

Figure 12: *Roasted Ethiopian Bean Comparison*

The green beans were still subject to scattering effects and heavy attenuation, but the roasted beans were much more consistent, due to their reduced moisture content.

Faculty Advisor: Dr. Mark Martin | Industry Sponsor: Dr. Joshua Mendez

chrisk@pdx.edu | hensan@pdx.edu | kamal@pdx.edu | mwallace@pdx.edu