



Physical Contamination Inspection via a Microwave Imaging System in the Food and Beverage Industry

C.I. Maraloiu⁽¹⁾, J.A. Tobon Vasquez⁽²⁾, M. Ricci⁽²⁾, L. Crocco⁽³⁾, R. Scappaticci⁽³⁾ and F. Vipiana⁽¹⁾

(1) Dept. Electronics and Telecommunications, Politecnico di Torino, 10129 Torino, Italy

e-mails: calin.maraloiu@polito.it, francesca.vipiana@polito.it

(2) Wavision s.r.l., 10129, Torino, Italy

(3) Institute for Electromagnetic Sensing of the Environment, National Research Council, 80124 Napoli, Italy

Physical contamination inspection is a crucial verification step that must be addressed by production plants in the food and beverage industry to guarantee the conformity of the manufactured products, the safety of the consumers and the preservation of the brand reputation. A microwave imaging (MWI) system is here exploited to scan items moving on conveyor belts at high speed, and to detect, in real time, physical foreign intrusions, often unintentionally caused by malfunctioning equipment or improper handling. The possible advantages are multiple: the technique is non-destructive and harmless for both workers and products, the setup is cost competitive, the system is low power, and the maintenance is undemanding.

The present work describes the latest progress in the study, development, validation and testing of in-line MWI inspection systems for industrial food quality assessment. The considered setup comprises a tailored compact multi-antenna module that can be mounted on a production chain conveyor belt. Foreign bodies, due to their different electrical properties, alter the incident electromagnetic radiation sourced by the antennas, and this is key in developing 3D dielectric contrast maps, which allow locating the intrusion [1].

More in details, our targets are water and oil-based products. The investigation frequency range is an important aspect to suitably analyze the tested items, due to resolution and penetration depth trade off, characterizing the materials involved. To improve the quality and accuracy of the inspection algorithms, we adopt multi-frequency strategies to enhance the location of the contaminated spots and reduce the impact of noise [2].

Finally, combination of MWI strategies with machine learning algorithms [3] will be also investigated to increase the accuracy of the detection rate; binary and multiclass classifications will be performed to reduce the number of false positive and false negative cases and therefore, improve the reliability of the MWI systems.

This work is part of the project PNRR-NGEU which has received funding from the MUR – DM 117/2023. This research was supported in part by the project PON Research and Innovation, “Microwave Imaging and Detection powered by Artificial Intelligence for Medical and Industrial Applications (DM 1062/21),” and in part by the PRIN project “BEST-Food, Broadband Electromagnetic Sensing Technologies for Food Quality and Security Assessment”; both projects are funded by the Italian Ministry of University and Research (MUR). The research is supported also by the project “INSIGHT-FOOD – An innovative microwave sensing system for the evaluation and monitoring of food quality and safety”, funded by the Italian Ministry of Foreign Affairs and International Cooperation (MAECI).

References

- [1] M. Ricci, J. A. Tobon Vasquez, R. Scappaticci, L. Crocco, and F. Vipiana, “Multi-antenna system for in-line food imaging at microwave frequencies,” *IEEE Transactions on Antennas and Propagation*, **70**, 8, p. 7094 – 7105, 2022, doi: <https://doi.org/10.1109/TAP.2022.3177436>
- [2] C. I. Maraloiu, J.A. Tobon Vasquez, M. Ricci, L. Crocco, and F. Vipiana, “Multi-Frequency Microwave Imaging Inspection for Industrial Food Quality Assessment,” accepted to *19th European Conference on Antennas and Propagation (EuCAP)*, Stockholm (Sweden), 30 March – 4 April, 2025
- [3] A. Darwish, M. Ricci, J.A. Tobon Vasquez, C. Migliaccio, and F. Vipiana, “Near-field microwave sensing technology enhanced with machine learning for the non-destructive evaluation of packaged food and beverage products,” *Sci. Rep.*, **14**, 13413, 2024, doi: <https://doi.org/10.1038/s41598-024-62287-6>