stories in the fields of cancer therapy and treatment of chronic pain.

After four years working with medical-grade devices, our team has gained during 2023 two memorable milestones for the LEANFA history: the first official FDA certification (through the so called 510k process) for an RF-driven multi-probe generator and the ISO 13485 quality certification, both precious excellence seals that give us even more energy to progressively expand the scope of our solid-state microwave technology towards a better life, worldwide.

About the author

Marco Fiore received his M. Sc. degree in electronics engineering at Politecnico di Bari, Italy. He has worked for more than 15 years in the field of digital telecommunications and broadcasting, from design tasks to operational management, always dedicated to implement deep interaction between high-frequency power electronics and programmable digital devices. He is co-founder of LEANFA in 2014, fully devoted to foster new business opportunities in Industrial, Scientific and Medical fields by means of innovative solid-state generators powered by distributed software applications.

Current Research Activities on Microwave Technologies at the Universidad Politécnica de Cartagena

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After twenty-five years at the Universidad Politécnica de Cartagena (UPCT), the research group "Electromagnetismo y Materia" (GEM) has consolidated its structure with four professors, one senior lecturer, one lecturer, and three assistant researchers. It has also continued to receive funding for microwave and electromagnetic technology-related projects from national, regional, and European programs. While it's challenging to categorize everything we do, over the past few years, we have mostly worked with permittivity measurement, microwave filter design, microwave cloth dryers, calibration techniques, microwave-assisted waste recycling, radiomap generation, microwave sterilization, and axion search measurements using microwave haloscopes.

Methods for measuring permittivity

An original approach for characterizing the permittivity of liquids and granular materials in relation to temperature, density, and moisture content changes based on the Dielectric Kit for Vials from the ITACA Institute at the Universidad Politécnica de Valencia has been developed within the GEM, allowing us to characterize a significant number of materials, including cloth aggregates, cypress and rockrose biomass, coffee, quinoa (**Figure 1**), etc. Furthermore, for materials with non-canonical forms, we have refined our inverse measurement techniques to reduce the uncertainty of sample position within waveguides [1, 2].

High-power stop-band coaxial filter design

High-power band-stop coaxial filters offer significant benefits to microwave applicators because they make it possible to add instruments and probes that could be used to enhance or monitor microwave heating applications. As seen in **Figure 2**, the initial use of these filters was the addition of metallic stirrers inside the microwave applicators that did not exhibit any discernible leakage. This avoided bearing ball heating and maintained radiation levels within allowable bounds [4].

However, further applications are being explored and will be shown to the microwave-heating community in the next few months.

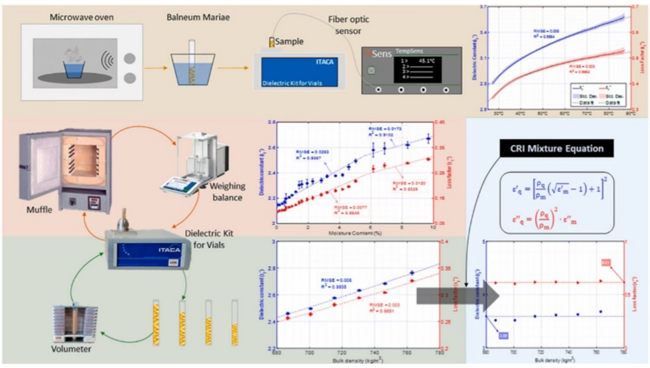

Figure 1. Characterization of quinoa permittivity under several temperature, moisture content, and density conditions. Figure reproduced from [2] under a Creative Commons license [3].

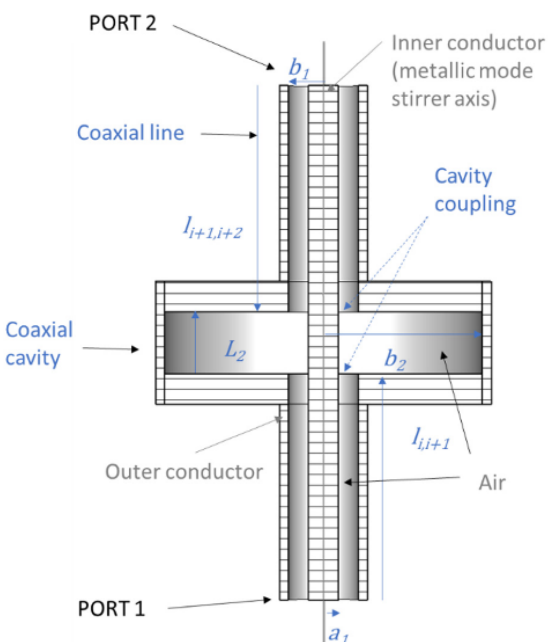

Figure 2. Cross section of coaxial cavity used for high-power band-stop filters allowing the introduction of metal axes in microwave ovens. Figure reproduced from [4] under Creative Common license [3].

Calibration techniques

In GEM, a significant amount of work has gone into creating our own calibration methods.

We have focused mainly on coaxial-to-waveguide transitions, and now we are able to characterize those devices both under monomode and multimode conditions [5]. We are currently developing our own methods for calibrating coaxial probes.

Microwave-assisted waste recycling

Over 3 million metric tons of end-of-life tires (ELTs) are produced annually in Europe, posing serious storage and environmental issues.

Under grant agreement number 870,000, the European Union's Horizon 2020 research and innovation program funded the project "VALUE-RUBBER: Recycling technology to introduce rubber from end-of-life tires into production lines as a virgin rubber substitute." This allowed us to design and evaluate a microwave-assisted applicator that was able to recycle rubber from tires in the automotive sector by devulcanizing it and performing further mechanical processing [6].

Additionally, at GEM, we are creating microwave applicators to recycle wastewater from landfills or car washes. Under the project "Application of low-loss dielectric molds to improve the efficiency of microwave evaporation for wastewater recovery" under grant reference 22234/PDC/23, this research has been funded by the Fundación Séneca, a regional research and technology foundation from the Gobierno de la Región de Murcia. This funding implies collaboration with the firm GETRAME S.L.

Axion and gravitational waves detection with microwave cavities

The axion is a hypothetical particle that possesses the properties required to make up the dark matter.

Currently, numerous worldwide collaborations, notably RADES (Relic Axion Dark-Matter Exploratory Setup), in which GEM participates, are planning and carrying out experiments employing microwave resonant cavities to detect the presence of the axion in the galactic halo that surrounds us. If this discovery is confirmed, one of the most pressing questions in current astronomy—understanding the nature of dark matter—will be addressed. This research began in 2016 and continues with the project "Development of broadband haloscopes for axion detection in BabyIAXO and solenoid magnets. Improvement in volume, quality factor, noise temperature, and mass range" under grant agreement PID2022-137268NB-C53. This research work was totally funded by the State Research Agency of Spain (Ministry of Science and Innovation) and FEDER (Fondo Europeo de Desarrollo Regional- a European Regional Development Fund) funding. Our goal in this project is to construct microwave cavities with the best quality factor, volume, and the ability to tune in the widest frequency range possible while coordinating at both the national and European level. In this case, paradoxically, the power level of the detected signals from axion conversion is expected to be more than 260 dB below the usual power levels used in microwave heating applications, but the expertise in microwave cavity design can help a lot in the construction of this type of detector (microwave haloscope) [7]. The group participates too in the ERC Synergy project "DarkQuantum", which will research in the next six years on new cavity – qubit systems for reducing the noise in axion detection experiments below the standard quantum limit.

These detection techniques can also be applied to the detection of gravitational waves, and we are currently cooperating with researchers from the Instituto de Física Corpuscular (IFIC), at the Universidad de Valencia, and from the Institut de Física d'Altes Energies (IFAE) at the Universidad Autónoma de Barcelona to analyze and create microwave sensors capable of detecting gravitational waves at high frequencies.

Other research activities:

Other recent research activities include the optimal generation of radioelectric maps using interpolation techniques, the use of microwave energy to improve plant germination and food sterilization, and the development and construction of microwave-assisted cloth dryers (also funded by Fundación Séneca under grant agreement 21640/PDC/21), which may result in the grant of a new patent in the coming months.

In the next few months, a new research assistant will join the GEM research group (supported by Fundación Séneca under the Saavedra Fajardo program) and will conduct research on antennas for magnetic resonant imaging, expanding our study lines.

For further reading

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About the author

Juan Monzó Cabrera is Full Professor at the Universidad Politécnica de Cartagena (UPCT) related to telecommunication studies. He has worked as the Director of Transfer of Research Results Office and co-director of the Entrepreneurship Office at this university. He has also acted as the General Secretary for AMPERE EUROPE, as a member of the management committee of this association and as General Director of Research and Universities at the Regional Goverment of Región de Murcia. He is part of the research group of Electromagnetism and Matter in the UPCT, activity that has combined with innovation and technology transfer. Among other publications, he is co-author of more than 50 international publications in specialized scientific journals, as well as coinventor of 11 patents. He has been a researcher in around 50 projects with private and public funding, three of them with European funds. His research areas are related to microwave heating and drying, permittivity measurements, waste water recovery, axion detection, waveguide calibration procedures, electromagnetic compatibility and dosimetry and microwave oven design.