

QWED is a Polish SME founded in **1997** by 4 scientists / engineers from the Warsaw University of Technology (WUT), with complementary experiences in microwave technology, mathematical physics, and computational techniques. The primary task of QWED has been to manage the **development and industrial applications of QuickWave EM software**, originated by the company co-founders, led by Wojciech Gwarek, IEEE Fellow and Pioneer Awardee for the underlying concepts. *QuickWave* was acclaimed "gem" in IEEE Spectrum Magazine (1998) and awarded with e.g. the **European IT Prize** (1998) and the Prime Minister of Poland Award (1999).

QWED Sp.z.o.o., Warsaw, Poland

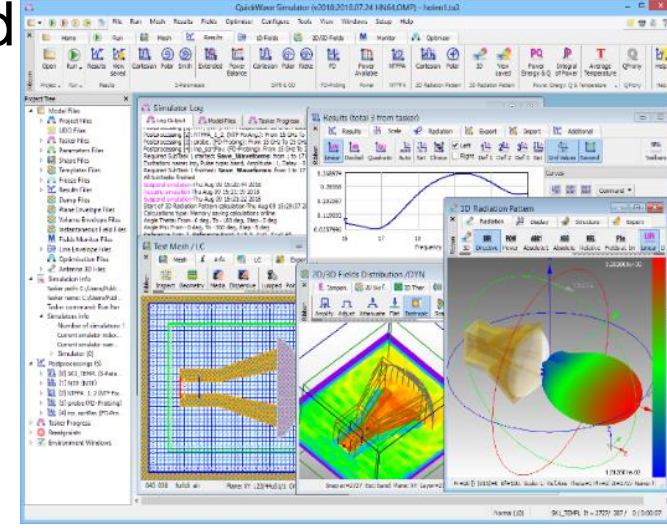
Malgorzata Celuch, e-mail: mceluch@qwed.eu

Marzena Olszewska-Placha, e-mail: molszewska@qwed.eu

Business branches & activities

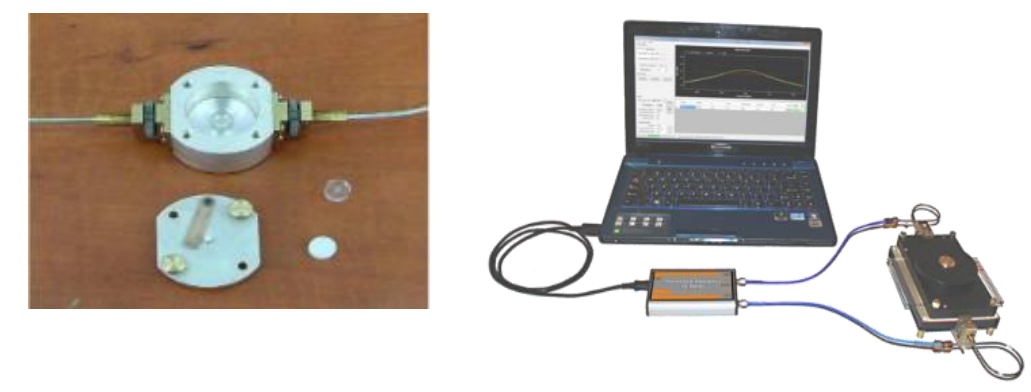
Electromagnetic & Multiphysics modelling & design software, 3D & BOR 2D tools from QuickWave family

Based on 300+ publications by:
Prof. W. Gwarek, IEEE Fellow, DML, Pioneer Award
Dr. M. Celuch, President of QWED



Text-fixtures for precise material measurements

Based on 300+ publications by Prof. J. Krupka, IEEE Fellow



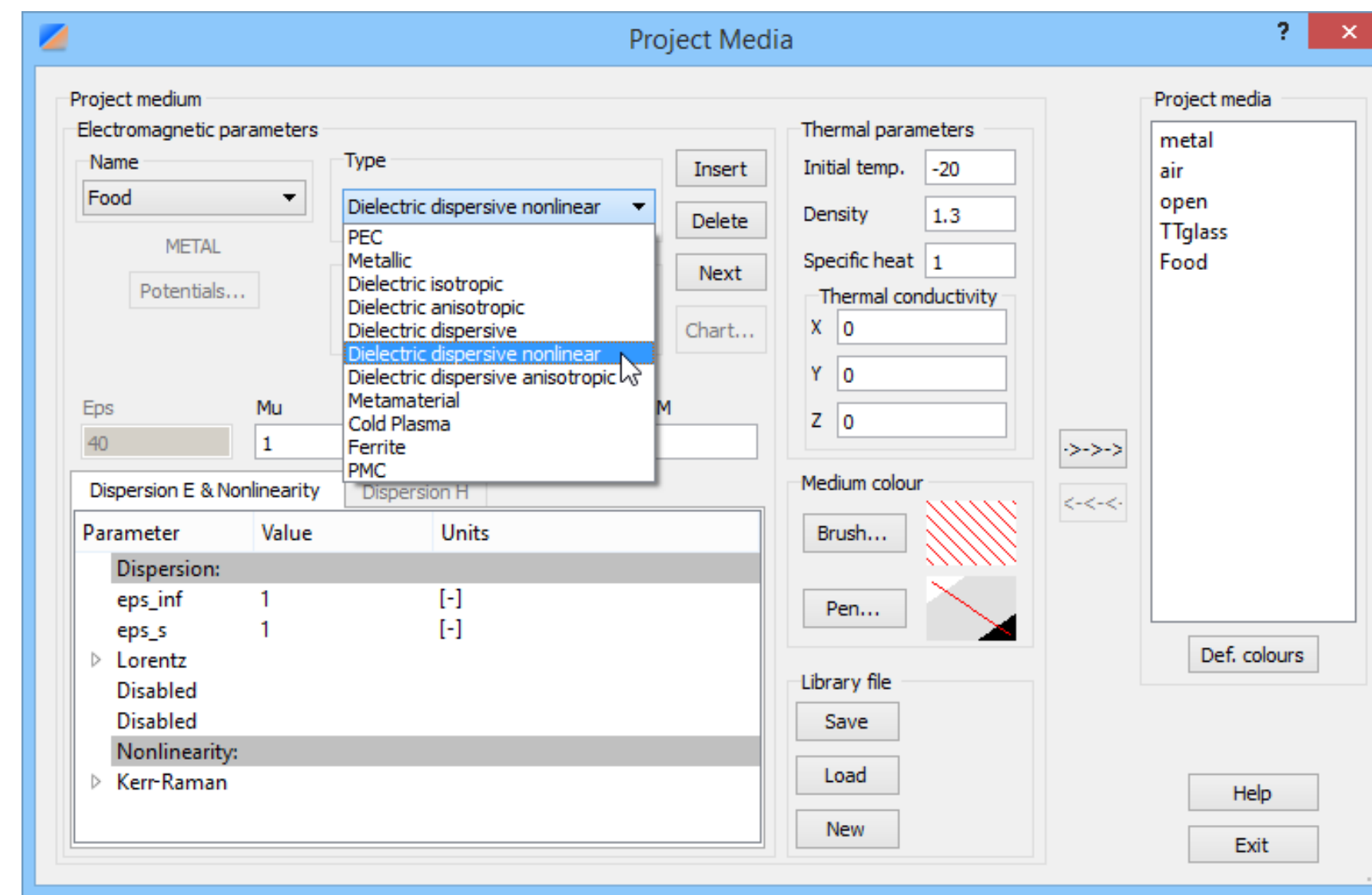
Consultancy & design services based on EM & material characterisation and measurements techniques

team of 10+engineers, 4 PhDs, 2 Profs
key areas: MW power appliances, customised resonators for material measurements, antennas & feeds

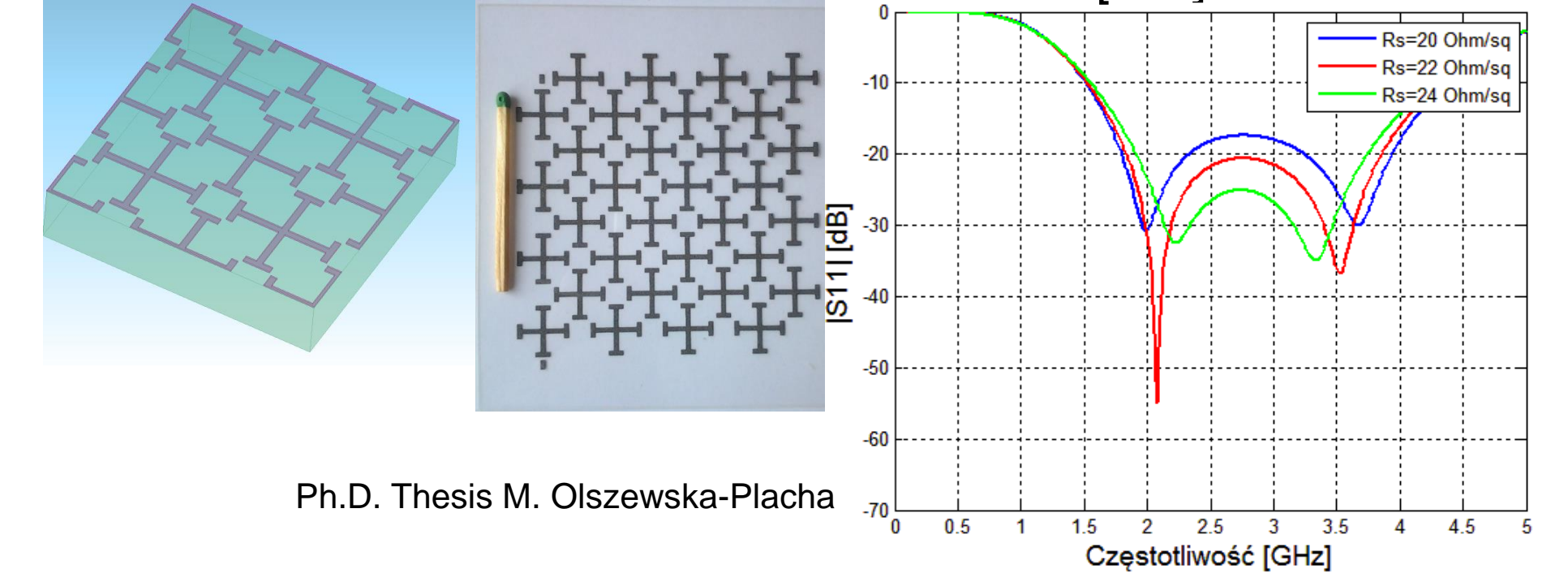
Public funded research projects

QuickWave

Electromagnetic & Multiphysics modelling software accounting for materials modelling at the continuum level.

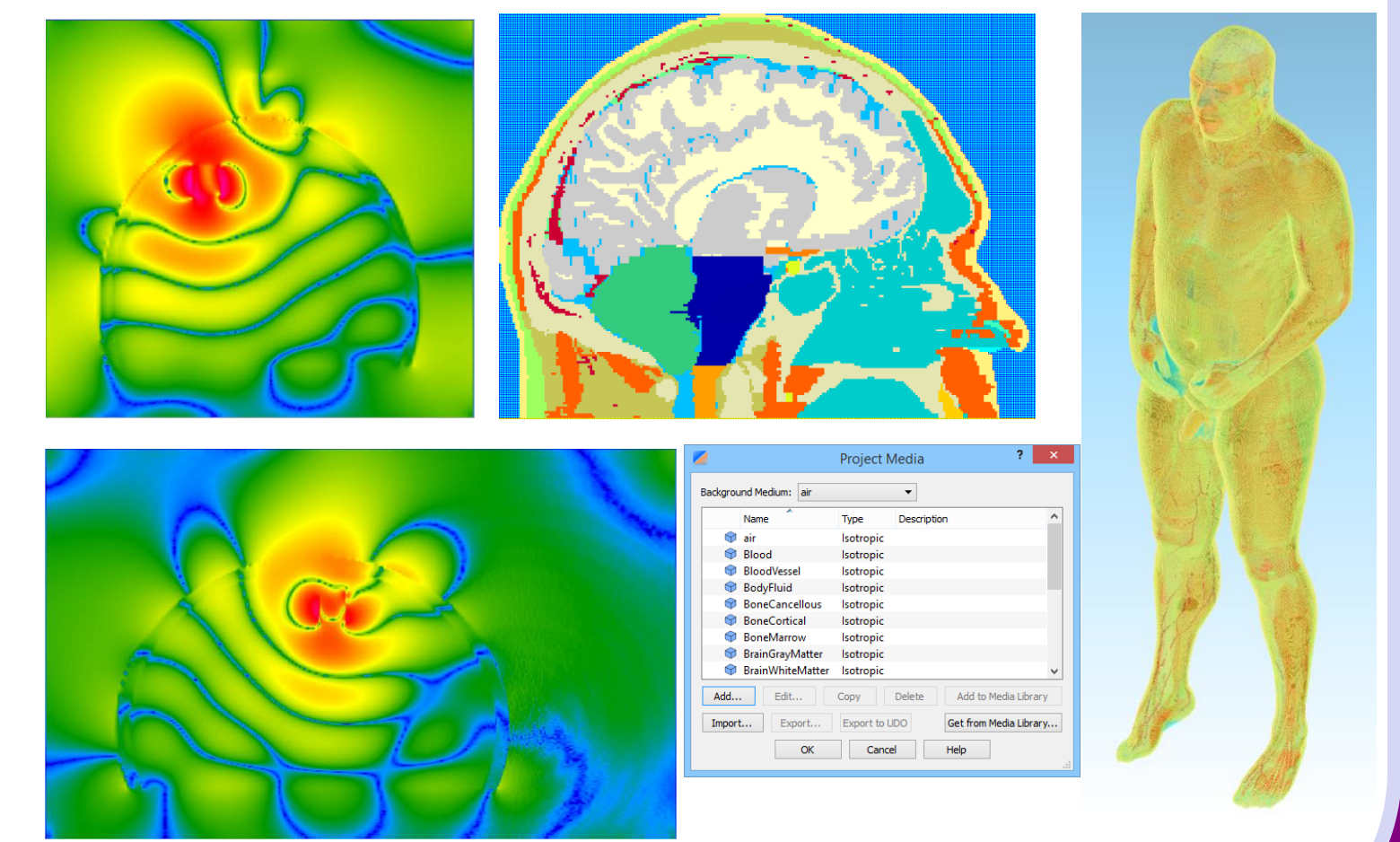


Thin sheets of **carbon-based polymer composites** described with **surface resistance** in $[\Omega/\square]$

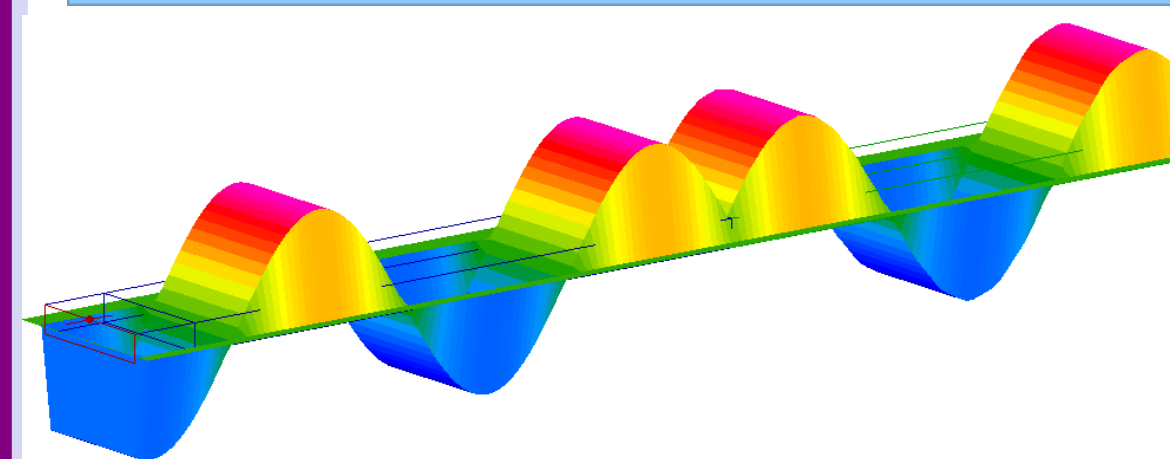


Ph.D. Thesis M. Olszewska-Placha

Macroscopic modelling of biological problems



Detection of inhomogeneities, e.g. tumours

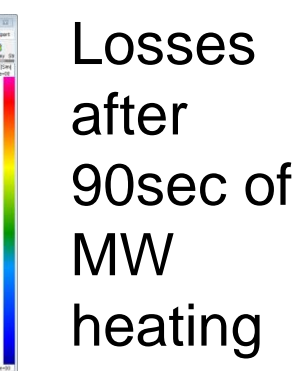
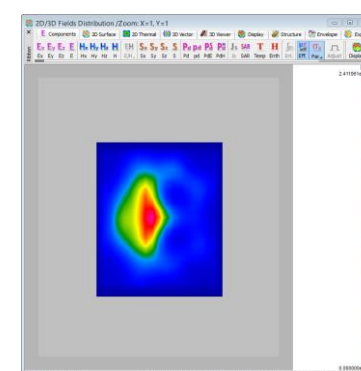
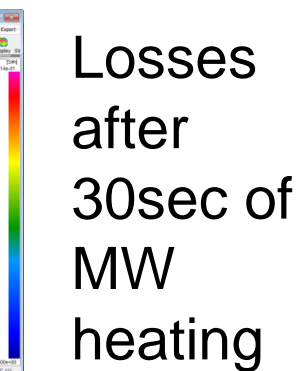
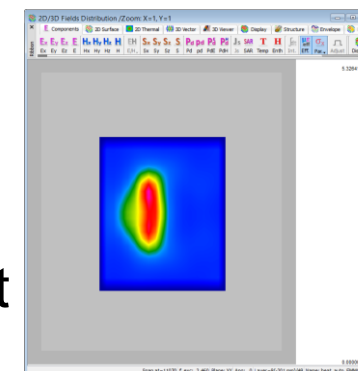
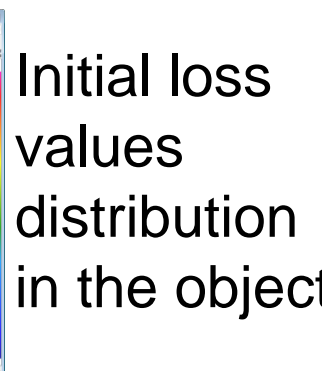
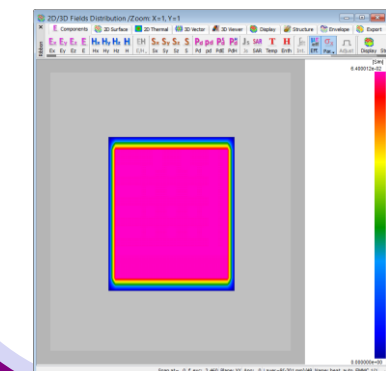


Material parameter dependent on process driving force

$$\text{Drude: } \epsilon_r(\omega) = \epsilon_\infty + \frac{(2\pi f_p)^2}{(j\omega 2\pi\nu_c - \omega^2)}$$

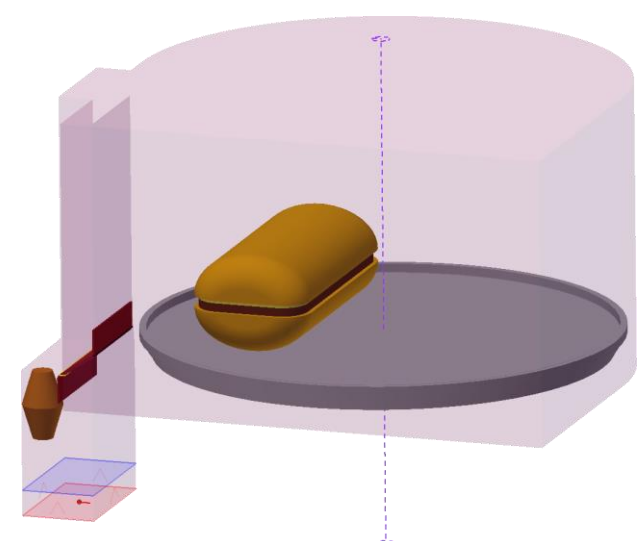
$$\text{Debye: } \epsilon_r(\omega) = \epsilon_\infty + \frac{\epsilon_s - \epsilon_\infty}{(1 + j\omega\tau)}$$

$$\text{Lorentz: } \epsilon_r(\omega) = \epsilon_\infty + \frac{\epsilon_s - \epsilon_\infty (2\pi f_p)^2}{((2\pi f_p)^2 + j\omega 2\pi\nu_c - \omega^2)}$$



Continuum modelling

- ✓ Electromagnetic
- ✓ Thermal
- ✓ Heat Flow
- ✓ Fluid Flow
- ✓ Parameters dependent on process driving force
- ✓ Interfaces to external modules



Obtaining equivalent parameters for continuum modelling

Imaging of multi-phase samples



Real scan/picture

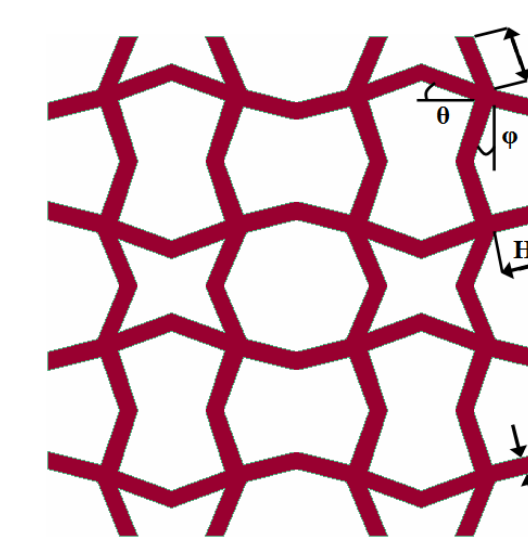
Image recognition



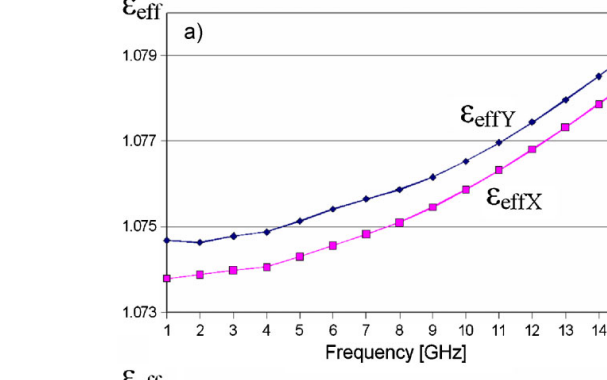
Simulation model

Effective equivalent parameters

Artificial structural materials – chiral materials



Effective parameters dependent on building material and chiral geometry



F. Scarpa et al. PSSB, vol.246, no. 9, 2009.

In-house measurements



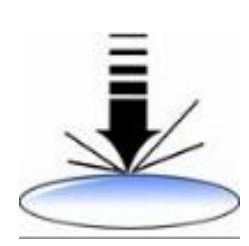
Popcorn susceptor

Measurements of Surface resistance

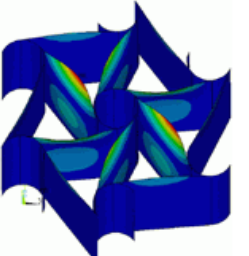
Simulation model

S. Bradshaw et al. Journal of Microwave Power & Electromagnetic Energy, vol.40, no. 4, 2007.

EU funded research projects



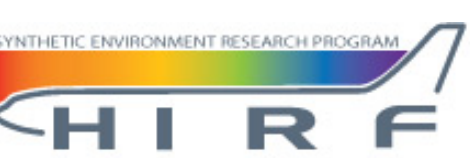
FP6 SOCOT – development and validation of an **optimal methodology for overlay control in semiconductor industry**, for the 32 nm technology node and beyond.



FP6 CHISMALCOMB – development, **modelling, and applications of chiral materials** → EM validation of **mixing rules**



Eureka E! 2602 MICRODEFROST MODEL – innovative software-based product development tool for **simulating and optimising heating and defrosting processes in frozen foods** in microwave ovens



FP7 HIRF SE (High Intensity Radiated Field Synthetic Environment) - **numerical modelling framework for aeronautic industry**



Eureka FOODWASTE – developing new **microwave treatment system** for high water content waste



ERA-NET MNT NACOPAN – applications and **modelling of nano-conductive polymer composites** → EM validation of mixing rules



NGAM2 – designing an **industrial device for thermal bonding of bituminous surfaces** with the aid of microwave heating



H2020 MMAMA (Microwave Microscopy for Advanced and Efficient Materials Analysis and Production) – accelerating the development of high efficiency solar cells through application and enhancement of material measurement techniques

Material measurements

Keysight Technologies
Split Post Dielectric Resonators for Dielectric Measurements of Substrates



Split-post dielectric resonators for low-loss laminar dielectrics measurements subject of **European Standard IEC 61189-2-721:2015** endorsed by Keysight Technologies Option 003 N1500A

Robust, easy-to-use with:

standard VNA



QWED portable low-cost Q-Meter



Recent SPDR-based designs for larger surfaces of:

large sheets of glass manual scan @ 1.9 GHz



semiconductor wafers automatic scan @ 10 GHz



QWED standard SPDRs @ 1.1, 2.45, 5, 10, 15 GHz



Ref.: www.qwed.eu

J. Krupka et al., *J. Eur. Ceramic Soc.*, vol. 21, pp. 2673-2676, 2001.

J. Krupka & J. Mazierska, *IEEE Trans. Instr. Meas.*, vol. 56, no. 5, 2007.

M. Celuch & al., *IEEE MTT-S IMS*, Boston 2019.

www.mmama.eu recent work under H2020-NMBP-07-2017 grant MMAMA No. 761036

A total of ca. **200 licences** have been implemented on **6 continents**

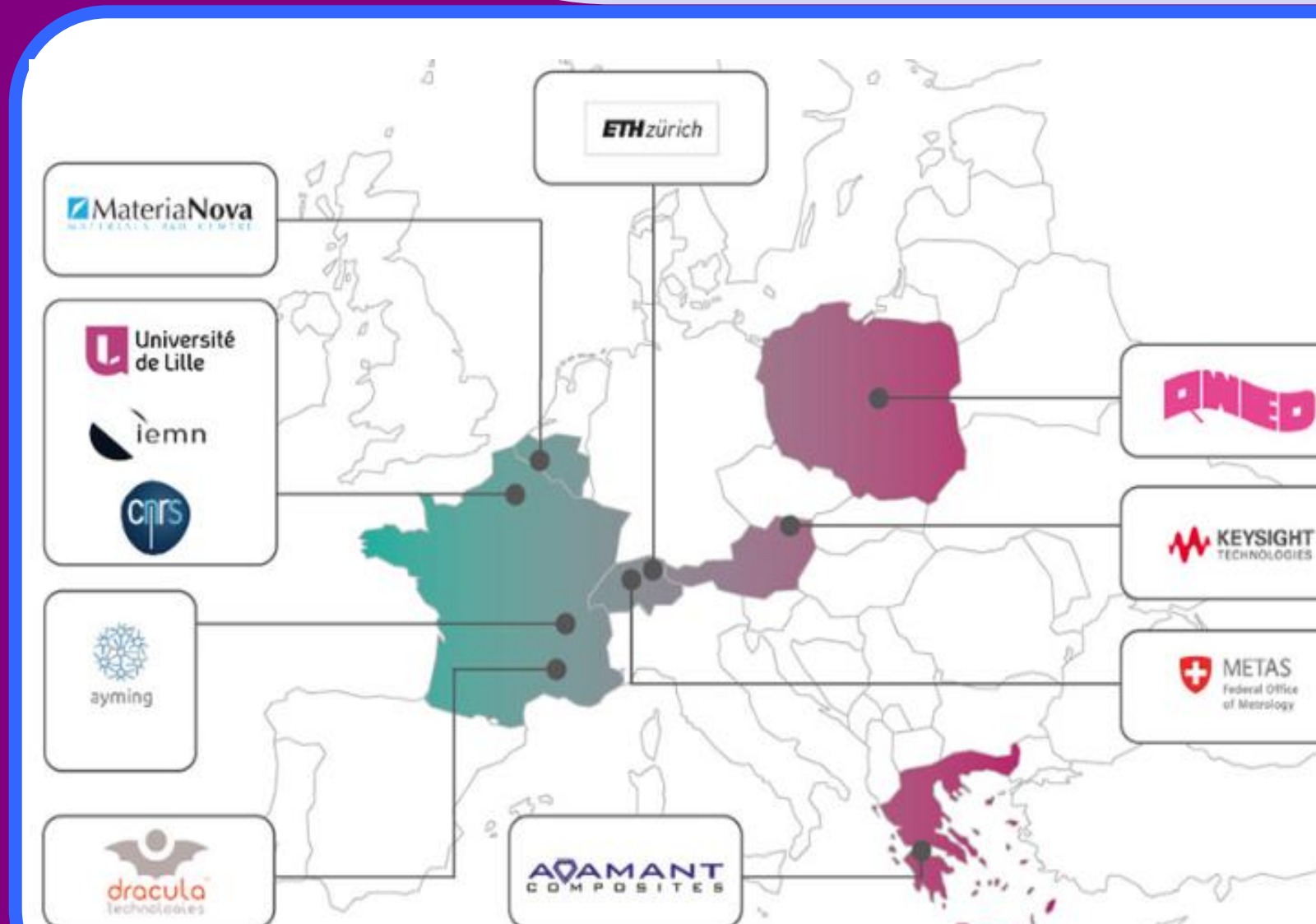
Diverse client base, from **radioastronomy laboratories** (e.g. NRAO in US) to world's leading **domestic microwave oven manufacturers**; **microwave imaging** is also supported by *QuickWave*, from biomedical devices to industrial microscopy of materials.

What distinguishes QWED from its larger competitors is openness towards **emerging technologies** and **niche markets**.

QWED seeks collaborations

- to develop **new material models** for QuickWave
- to develop **new physical solvers**
- to develop **interfaces to other physical processes**
- **promoting modelling & education**

QWED seeks collaborations in research projects



Acknowledgement

Recent QWED works concerning materials modelling has received funding from the European Union Horizon H2020 Programme (H2020-NMBP-07-2017) under grant agreement n°761036.