a Polish SME celebrating 25 years

in MHz to THz design, modelling, and characterisation

from IEEE-recognised scientific achievements

to products successful in IEEE-relevant industries

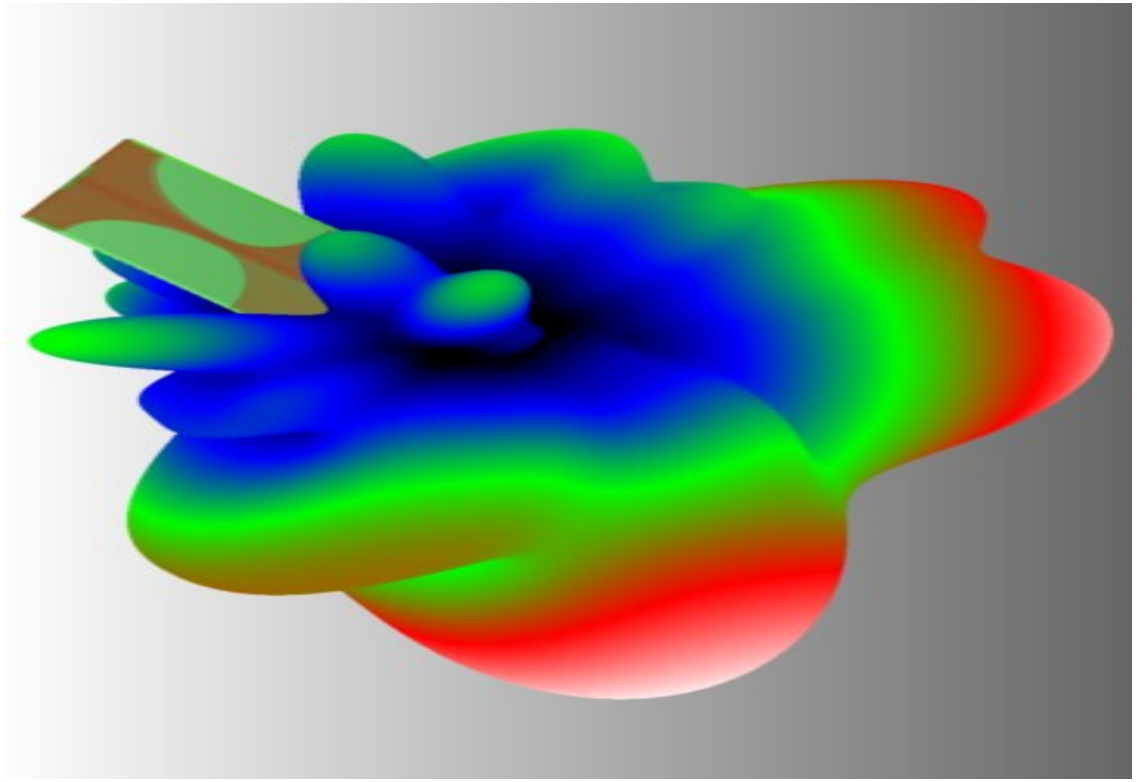
Dr. Malgorzata Celuch

President, Co-Founder, Senior Scientist
Co-Author of QuickWave™ simulation software
Team Leadr of EU H2020 MMAMA & NanoBat projects

IEEE Region 8 Committee Meeting, Warsaw, 1 April 2022

IEEE - Relevant

Ideas Published in IEEE Media & Awarded



IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. MTT-33, NO. 10, OCTOBER 1985 1067

Analysis of an Arbitrarily-Shaped Planar Circuit—A Time-Domain Approach

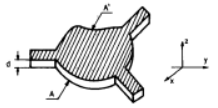


Fig. 1. A planar circuit.

WOJCIECH K. GWAREK

(*Invited Paper*)

$$\nabla V(x,y,t) = -L_s \frac{\partial \boldsymbol{J}(x,y,t)}{\partial t}$$

$$\nabla \cdot \boldsymbol{J}(x,y,t) = -C_s \frac{\partial V(x,y,t)}{\partial t}.$$

IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 36, NO. 2, FEBRUARY 1988

Computer-Aided Analysis of Arbitrarily Shaped Coaxial Discontinuities

WOJCIECH K. GWAREK

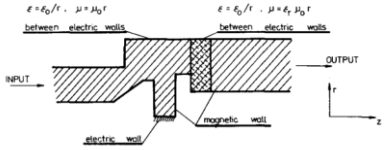


Fig. 2. Equivalent planar circuit of the discontinuity of Fig. 1.

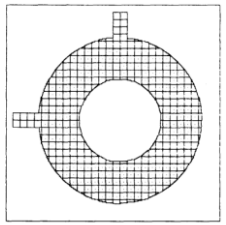


Fig. 6. A microstrip ring circuit as a grid of meshes.

738 IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 36, NO. 4, APRIL 1988

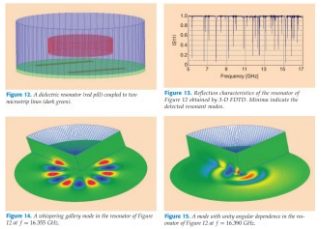
Analysis of Arbitrarily Shaped Two-Dimensional Microwave Circuits by Finite-Difference Time-Domain Method

WOJCIECH K. GWAREK

Applications in IEEE Research & Industries

Industrial Design of Axisymmetrical Devices Using a Customized FDTD Solver from RF to Optical Frequency Bands

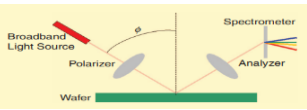
■ Malgorzata Celuch and Wojciech K. Gwarek



IEEE microwave magazine

FDTD for Nanoscale and Optical Problems

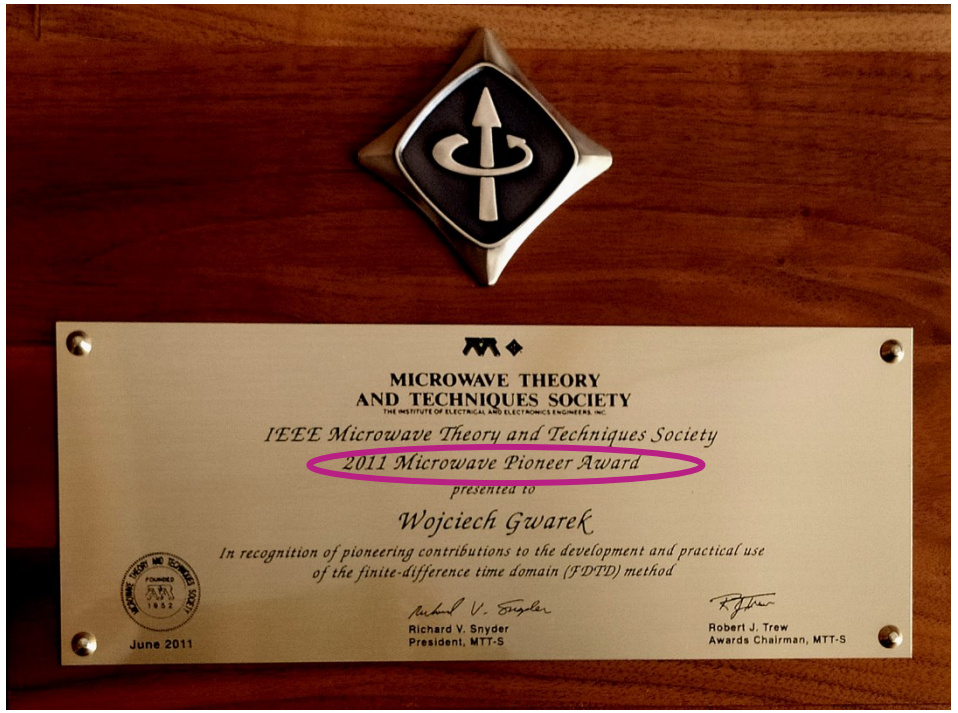
Bartlomiej Salski, Malgorzata Celuch, and Wojciech Gwarek



Prof. Wojciech K. Gwarek

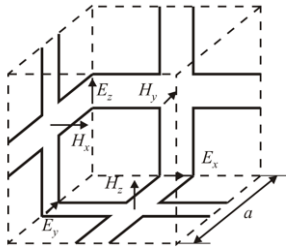
IEEE Life Fellow, MTT-S Pioneer Award, DML

QWED Co-Founder (1997) & First President (till 2017)

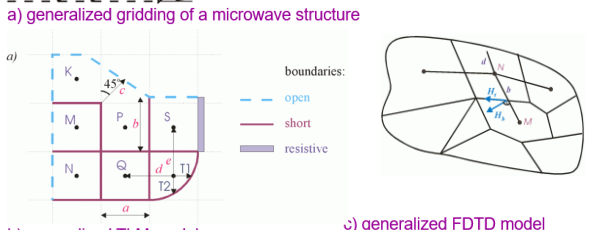


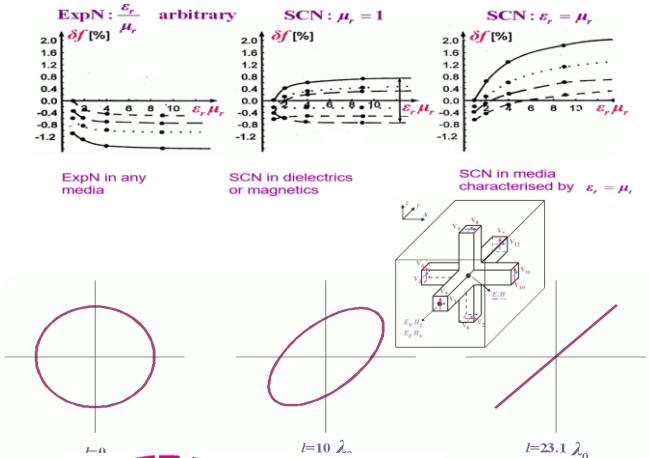
Contributions to the theory and applications of electromagnetic modelling
→ background and outreach of QuickWave™ software
→ research roots and market success of QWED

FDTD versus TLM
Theorem of Formal Equivalence



nodes: FDTD discretisation of Maxwell eqs.
connecting lines & stubs: TLM discretisation of Huygens principle

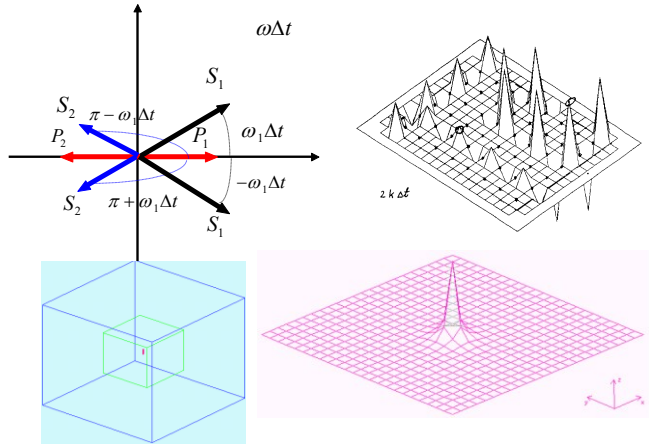




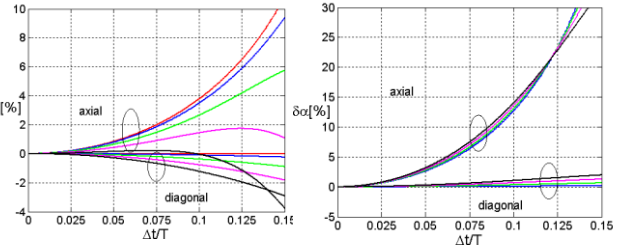
Generalised dispersion relations
Theory of P- and S-eigenmodes

$$P(\omega\Delta t)\ S(\omega\Delta t, \beta_x a, \beta_y a, \beta_z a) = 0$$

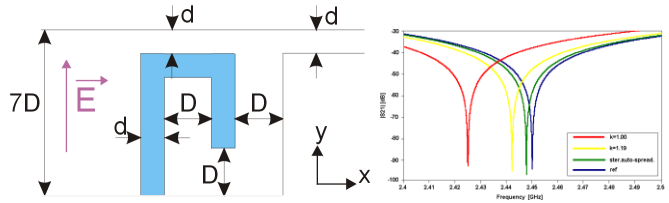
$$\omega_{ph}^2[-\omega_{ph}^2\mu\varepsilon + \beta_{xph}^2 + \beta_{yph}^2 + \beta_{zph}^2]^2 = 0$$



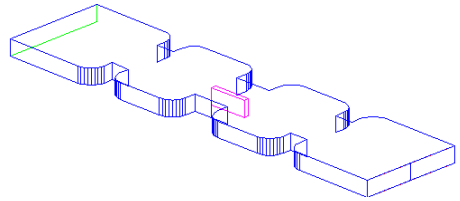
Dispersion in lossy media

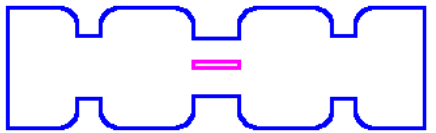


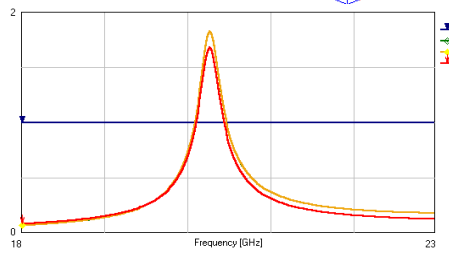
Field singularities

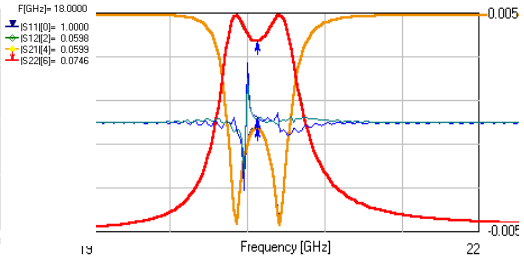


Generalised extraction of S-parameters in multi-modal transmission lines (incl. evanescent modes)

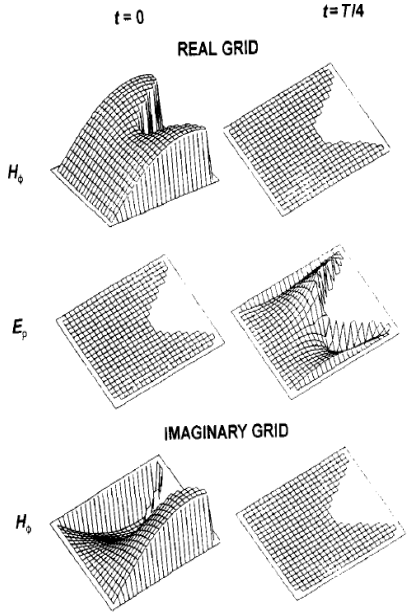




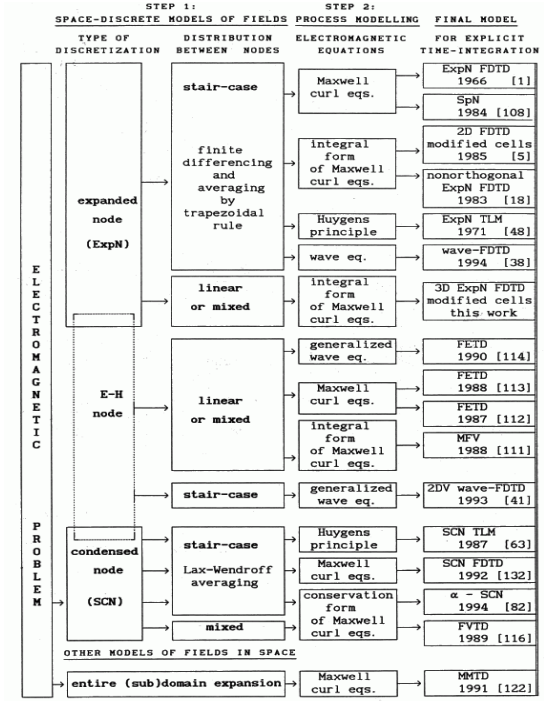




Periodic & vector 2D FDTD and TLM in real & complex form



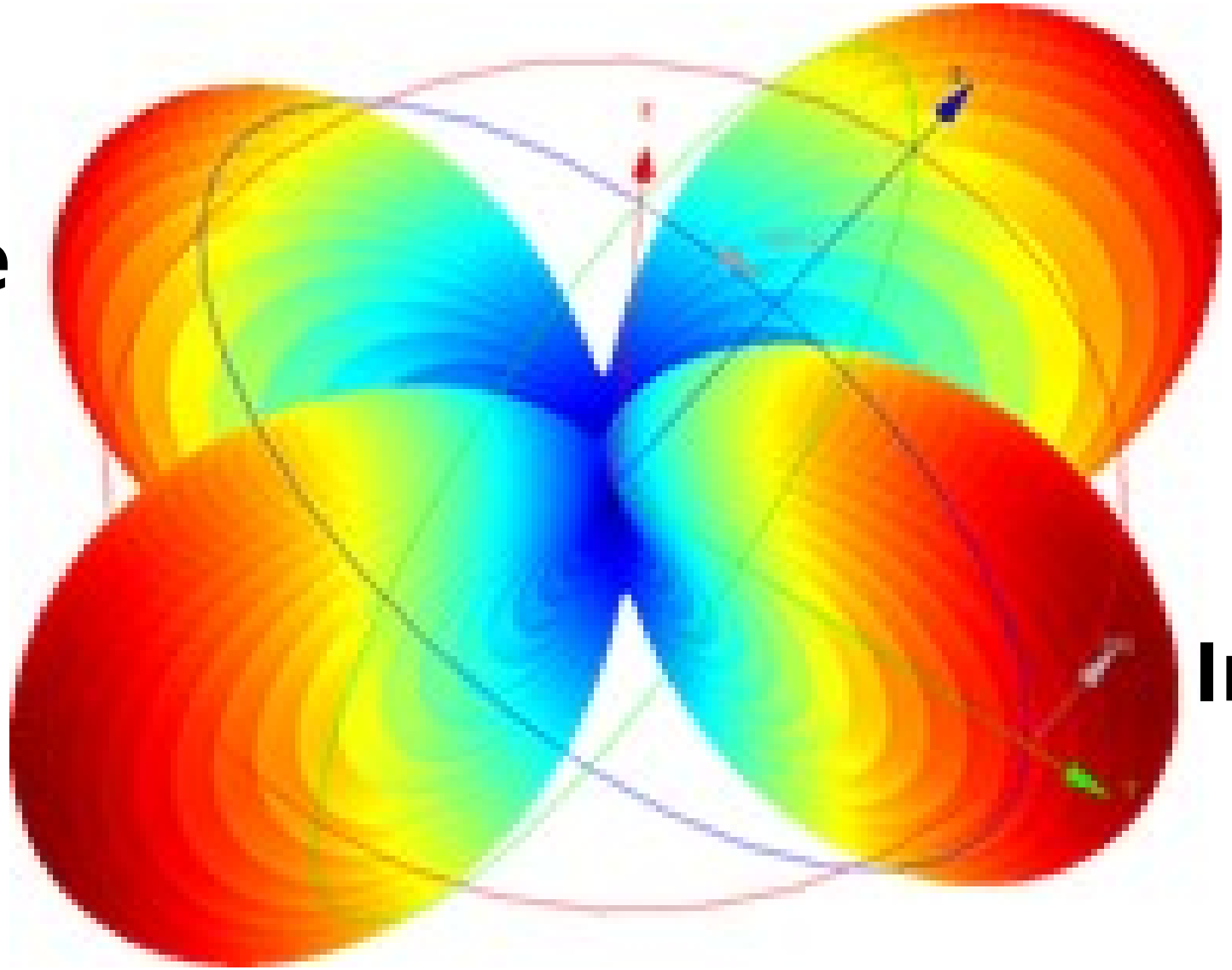
Classification of time-domain methods



Miscellaneous research results from M.Celuch, IEEE MTT-S Webinar, 14 September 2021

100% Polish

People



Ideas

Capital
company grown
on licence sales

Implementation
Production
Marketing
New Ideas

Polish Team of Internationally Awarded Experts

A happy blend of electronic engineers, multiphysics researchers, IT experts, business analysts, cross-media specialists

10 employed

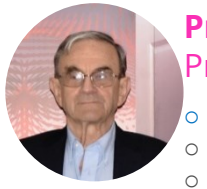
7 consultants

50% female

Core technical team- graduates of the Warsaw University of Technology

Dr. Malgorzata Celuch
President since 2017, VP 1997-2017

- **IEEE: MTT-1, VC PS WiE, AE JMMCT;**
- **former VC AES/AP/MTT JC PS**
- 35 yrs experience in mathematical modelling
- 25 yrs in corporate & research management



Prof. Wojciech Gwarek
President 1997-2017

- **IEEE: Life Fellow, Microwave Pioneer Award, DML**
- 50 yrs of experience in microwave technology
- 40 yrs in simulation software development

Dr. Marzena Olszewska-Placha,
VP for R&D

- **IEEE: Secretary PS WiE**
- 15 yrs of experience in simulation-based MHz to THZ design and consultancy
- 4 yrs experience in research management

Dr. Andrzej Więckowski
Senior in CAD

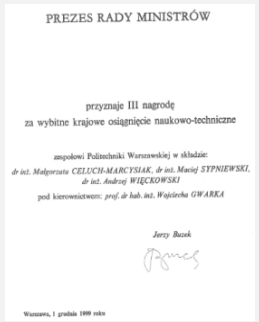
- 48 yrs of experience in computer-aided electronic engineering and engineering software development

Janusz Rudnicki, MSc.Eng,
VP for IT

- 22 yrs of experience in simulation software development
- 10 yrs in IT management

Dr. Maciej Sypniewski
Senior in CAE

- 35 yrs of experience in engineering software development and GHz measurements

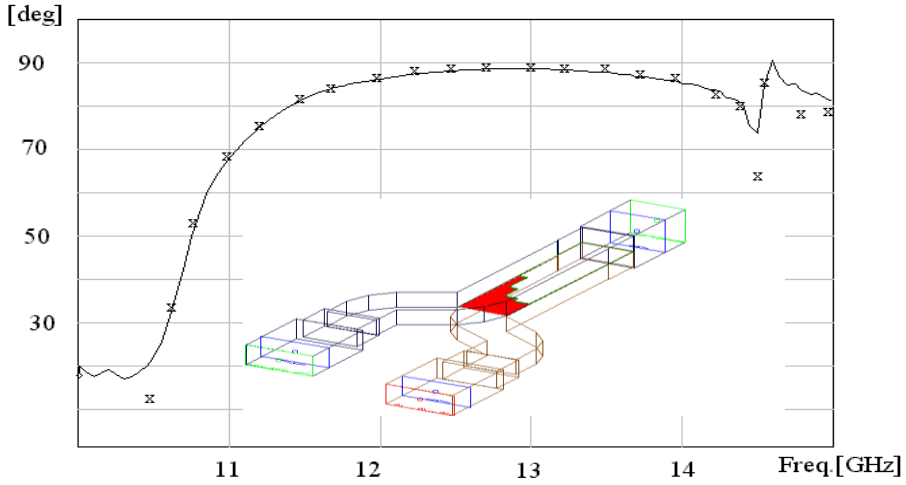


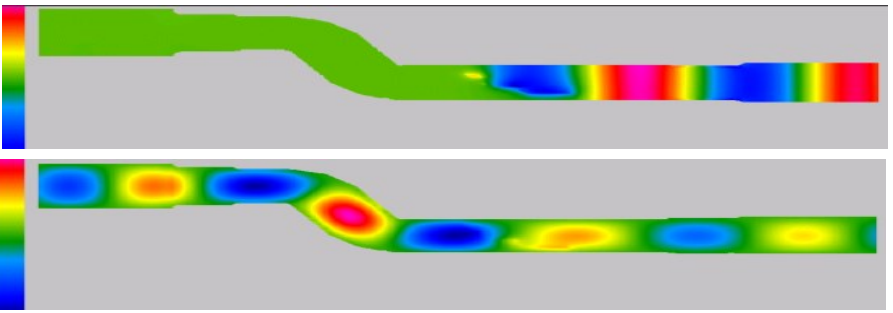
QuickWave™ applications in cosmic reseach & satellite telecommunication

Septum polariser by SES

design & measurements: Saab Ericsson Space
modelling: QWED, 1997

below: differential phase-shift



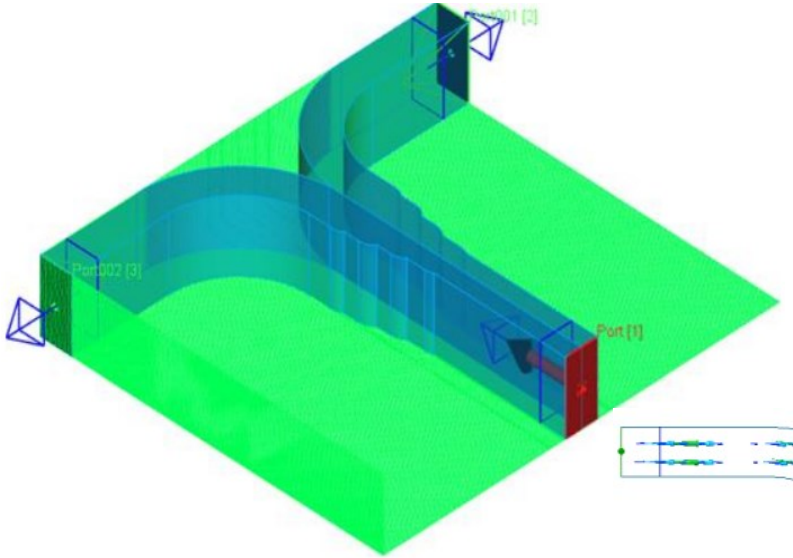


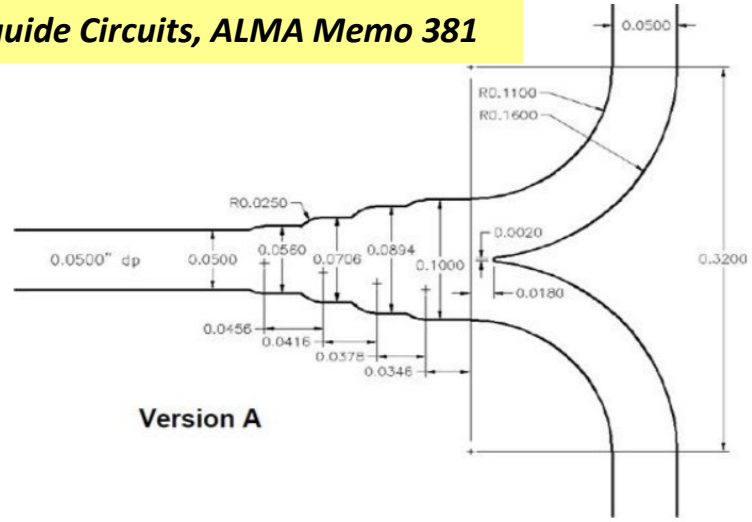
propagation of two polarisations

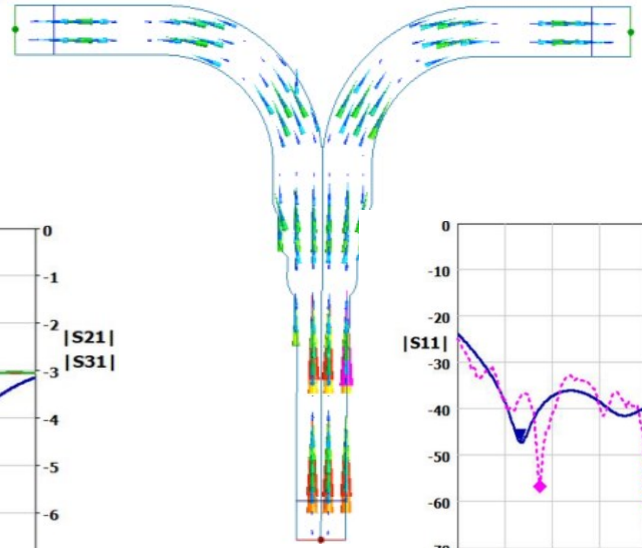
at centre frequency

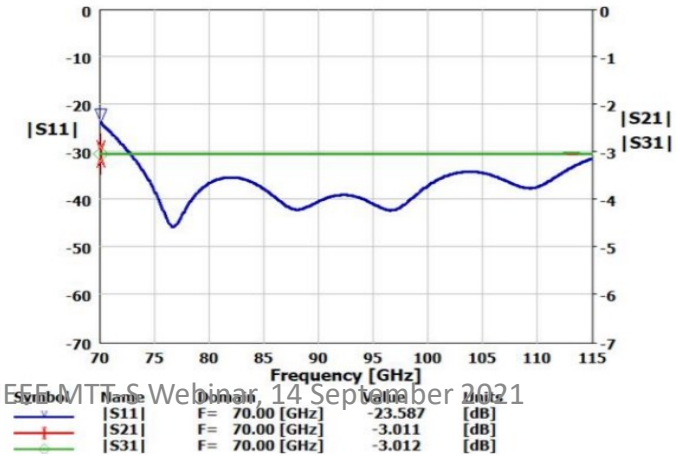
E-plane Y-junction by NRAO

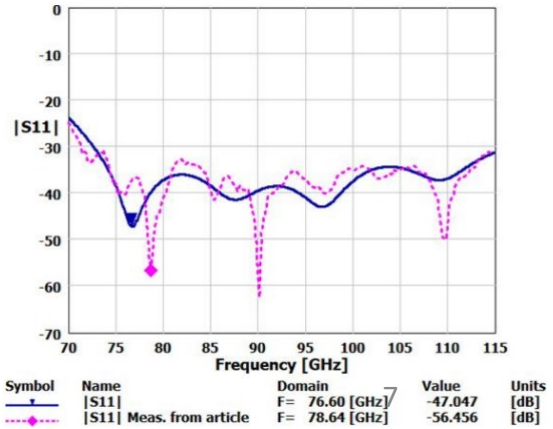
after A. R. Kerr, Elements for E-Plane Split-Block Waveguide Circuits, ALMA Memo 381





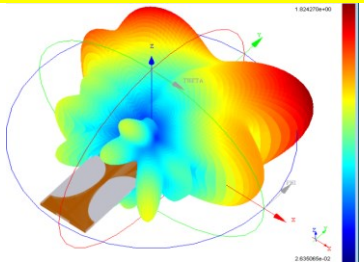




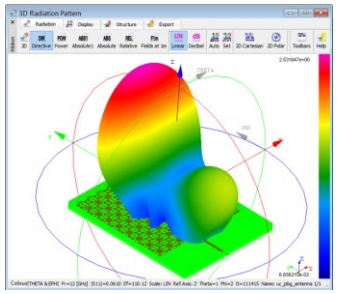


QuickWave™ further applications to the design of antennas & feeds

general 3D FDTD

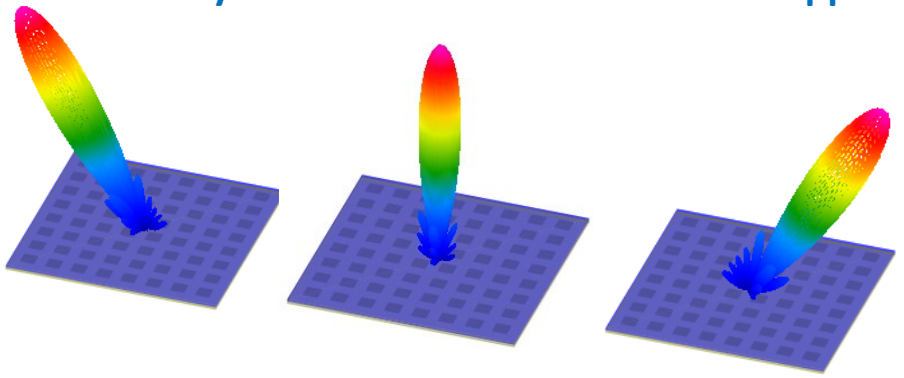


Balanced antipodal Vivaldi antenna
& 3D radiation pattern at 10 GHz.



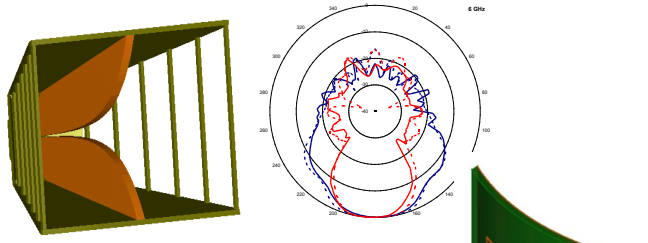
Aperture-coupled patch antenna
on uniplanar photonic bandgap substrate
& its radiation pattern at 12 GHz.

Antenna arrays for 5G and automotive radar application

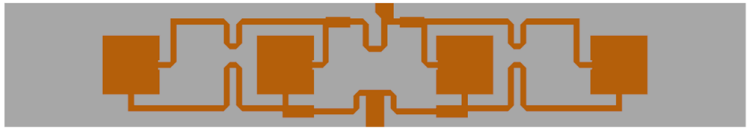


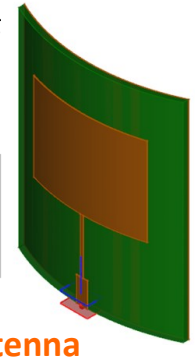
Designing and verifying tracking capabilities

Pyramidal horn antenna for military surveillance
measured (prof.B.Stec Warsaw Military Academy of Technology)
& simulated patterns

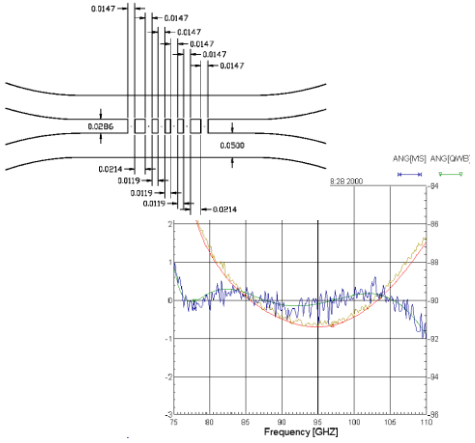


Planar antennas for smart bio-sensors



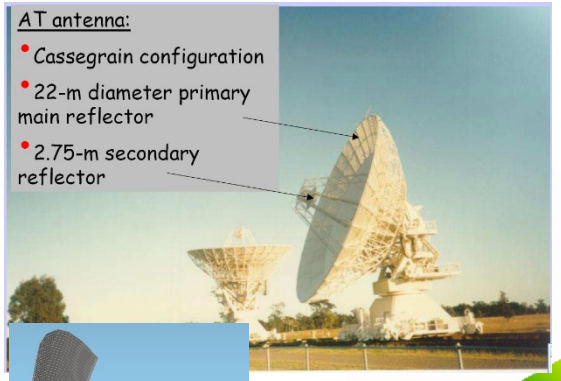


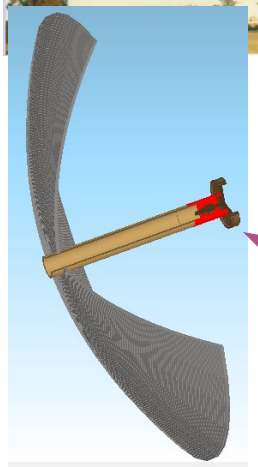
Antenna feed systems designed by NRAO

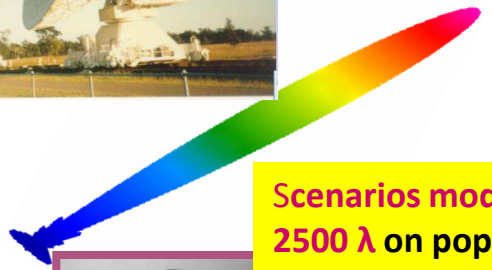


QuickWave 3D results at NRAO, see:
ALMA Memos 381, 343, 325, 278.

Large dual reflector antennas: *Cassegrain, Gregorian, etc.*







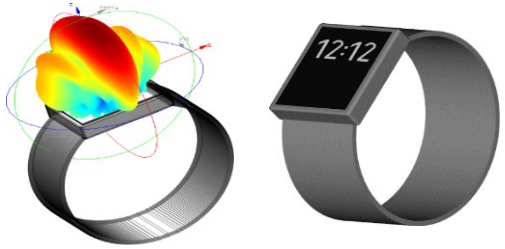
BOR FDTD

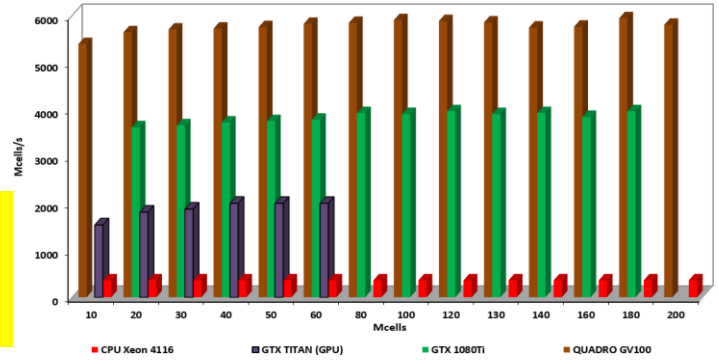
Unique, ultra-fast
vector 2D Bessel & FDTD hybrid solver
for design & analysis of axisymmetrical devices

Scenarios modelled full-wave by QW-BoR:
2500 λ on popular PC (64 GB)
5000 λ on top-shelf PC

QuickWave is optimised for speed
currently upm to 6000 Mcells/sec,
runs on professional & low-cost video cards

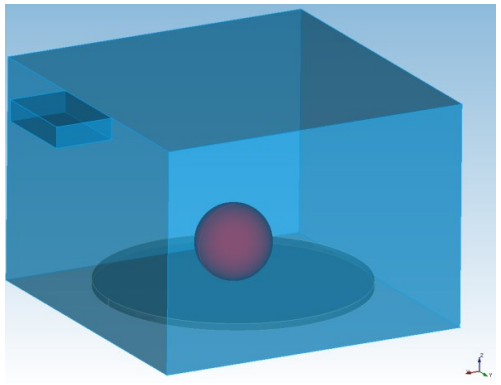
Smartwatch with embedded patch antenna

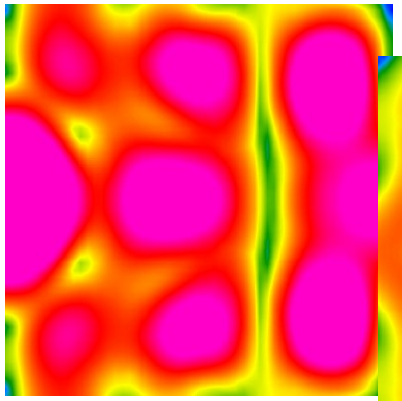




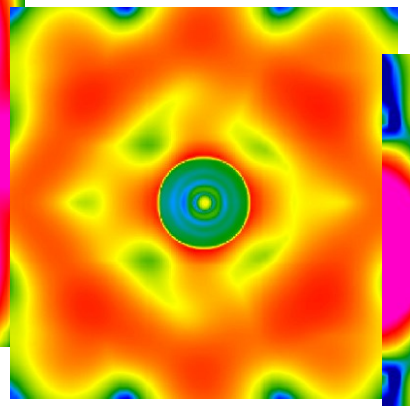
QuickWave™ modelling of EM field interaction with tissues

Separation of incident and diffracted fields (*option implemented per request of P.O.Risman, Malardalen Univesity*)

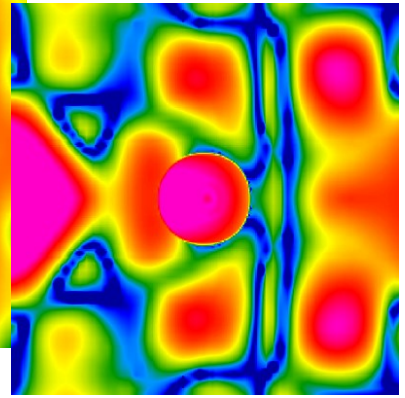




E-field in an empty cavity

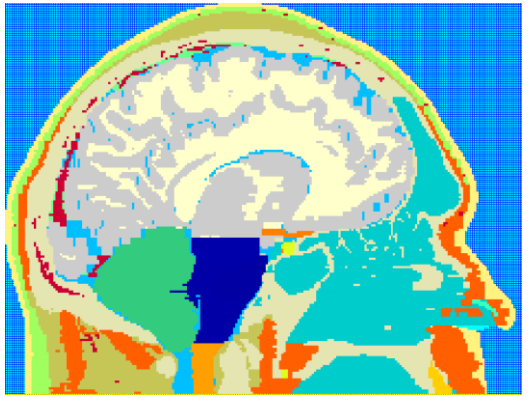


E-field in a loaded cavity

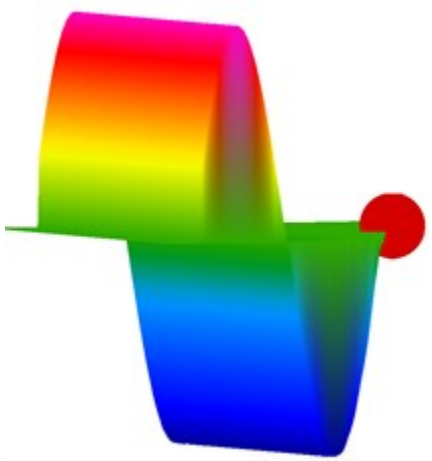


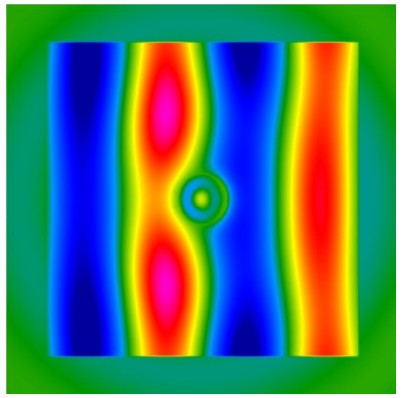
Scattered near-filed in cavity

Detection of inhomogenities in tissues

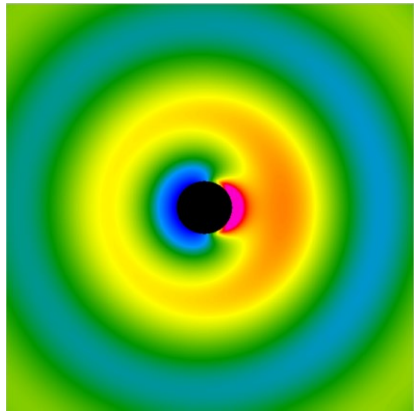


AustinMan model* converted to **QuickWave EM** software for Mälardalen University, Sweden

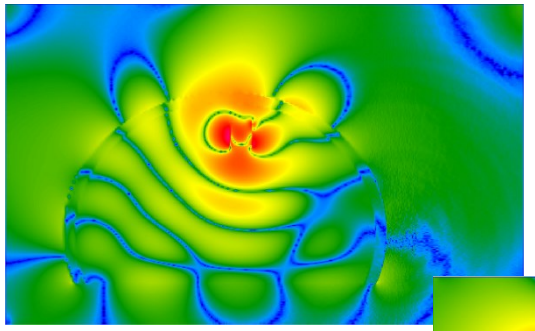


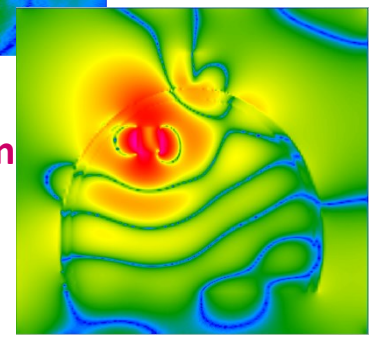


Total field
Focusing by the load
„exploding egg effect”



Diffracted field reveals cause of focusing: circumferential resonance



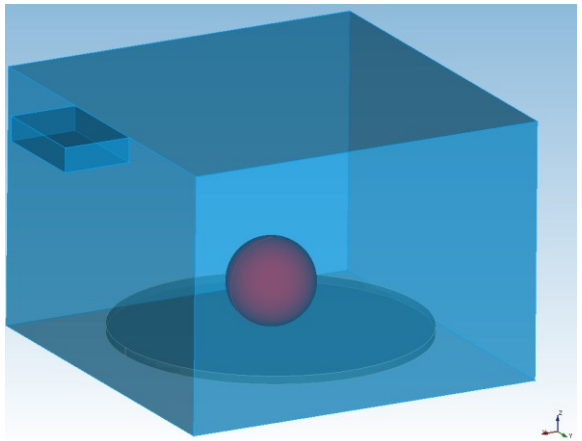


- ✓ **Tumours & haemorrhages detection**
- ✓ **Optimisation of multiantenna tomographic systems**

* https://sites.utexas.edu/austinmanaustinwomanmodels/

Ilustration of QuickWave™ Multiphysics Regimes in Elsevier Book

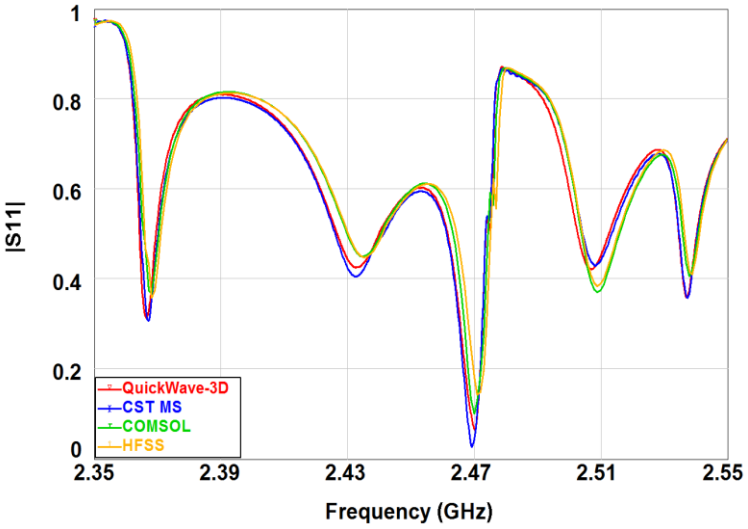
Simple microwave heating benchmarks & microwave heating phenomena studies*



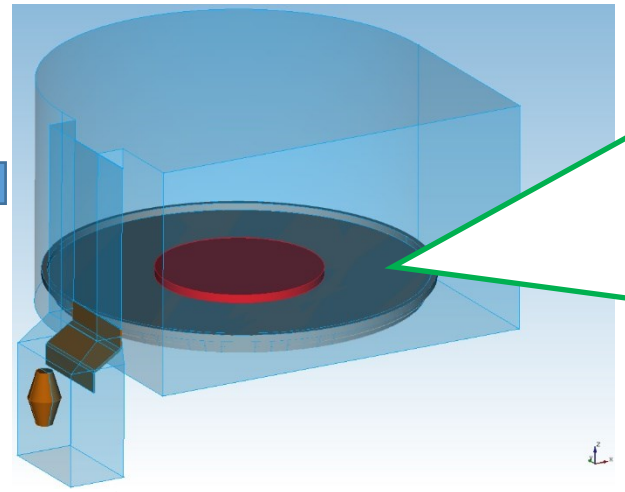
- heat transfer & load dynamics
- Load rotation & arbitrary movement during heating
- Source parameters tuning – regime for solid state sources
- Temperature dependence of material parameters

Freezing to file the state of the simulation

De-freezing on arbitrary computer & at convenient time

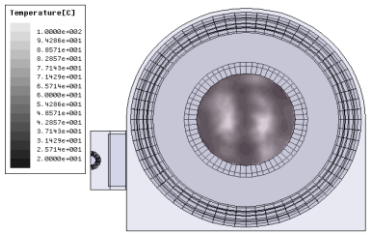


Design & analysis of real-life microwave oven cavities, incl. complicated cavity shapes and advanced feeding system*

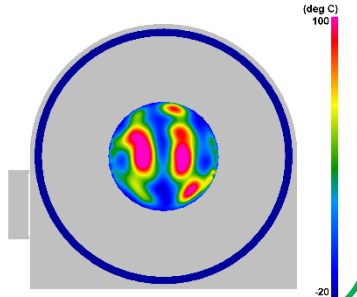


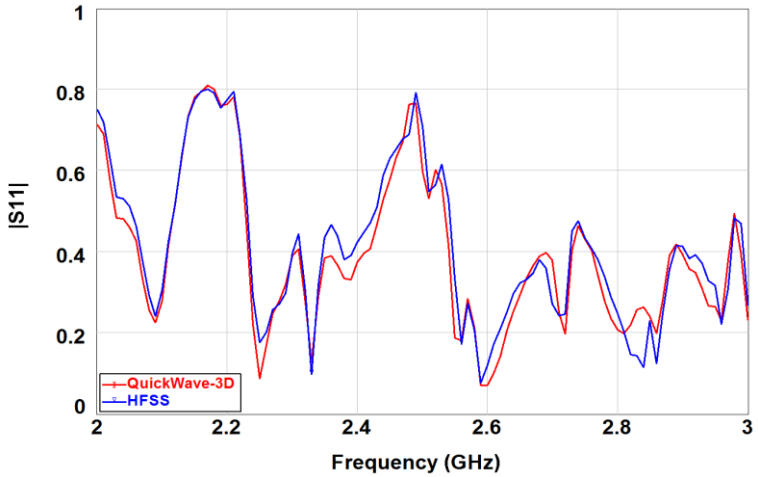
Courtesy of Whirlpool Inc. – Whirlpool MAX oven

HFSS v11



QuickWave 3D & BHM



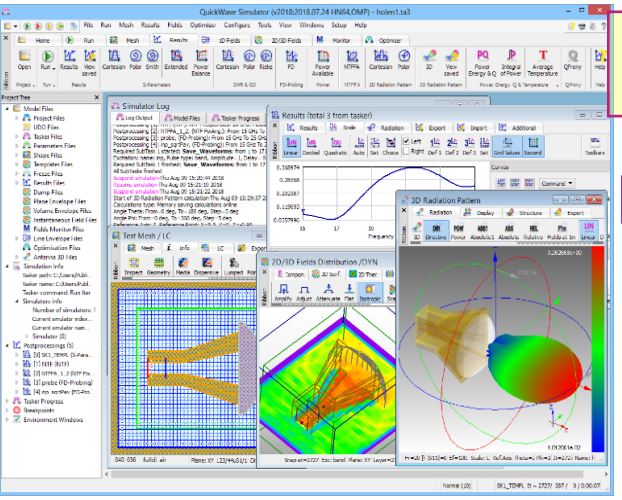


With QuickWave EM computation as fast as **1 min 18s** on a **low-cost video card** – supporting **all** graphic cards **with OpenCL**

* M.Celuch, P.Kopyt & M. Olszewska-Placha in eds. M. Lorence, P. S. Pesheck, U. Erle, *Development of packaging and products for use in microwave ovens*, 2nd Ed. Elsevier 2020.

25 years in a Nutshell

presented annually at IEEE IMS Show

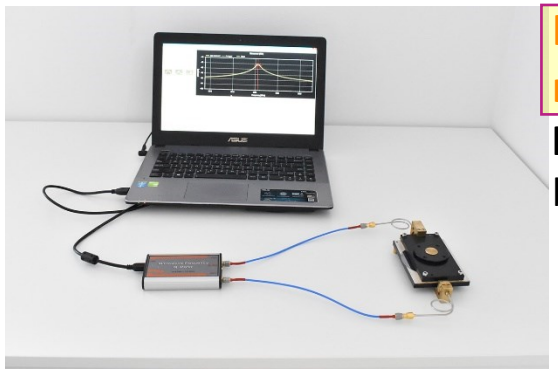


Electromagnetic simulation & design software, 3D & BOR 2D tools

based on 300+ publications by:

prof.W.Gwarek, IEEE Fellow, DML, Pioneer Award

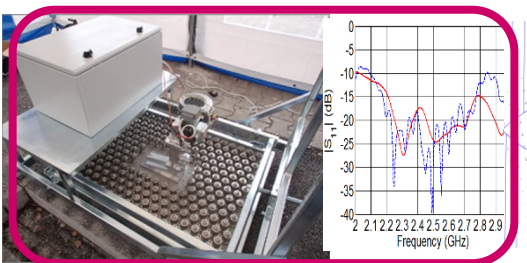
dr.M.Celuch, President of QWED

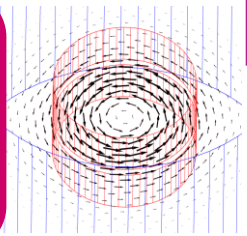


Instruments for precise material measurements

based on 300+ publications

by prof.J.Krupka, IEEE Fellow



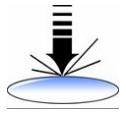


Consultancy & design services based on EM expertise & tools

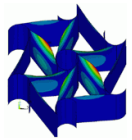
team of 10+engineers, 4 PhDs, 2 Profs

key areas: MW power appliances, customised resonators, antennas &feeds

R&D projects

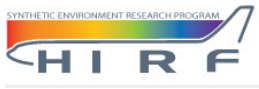


FP6 SOCOT – development and validation of an optimal methodology for overlay control in semiconductor industry, for the 32 nm technology node and beyond.



FP6 CHISMACOMB – 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 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

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

MMAMA (Microwave Microscopy for Advanced and Efficient Materials Analysis and Production) – EM modelling & characterisation for the development of high efficiency solar cells

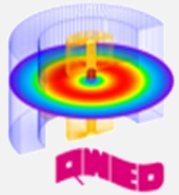
NanoBat - developing a novel nanotechnology toolbox for quality testing of Li-ion and beyond Lithium batteries with the potential to redefine battery production in Europe and worldwide.

ULTCC6G-EPac – development & application of novel ceramics for 5G & beyond

Exploring Synergies between Computer Modelling & Material Measurements

Commercial since 1997
QuickWave Simulation Software
~1000 licences implemented

THE EUROPEAN ICT PRIZE WINNER



Applicator design & model for parameter extraction

Modelling (EM, MW, multiphysics,...)
- waves in free space is "easy" Maxwellian
- wave interaction with matter is "complicated"...

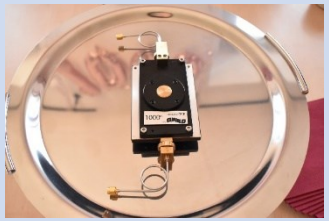
INNOVATION

Material measurements

Accurate material parameters (constitutive relations)

Commercial resonator test-fixtures since 2001

1000th unit sold in 2020



Open Platform Examples & Tools

QW-Modeller for QuickWave
Free general purpose 3D CAD modeller for QuickWave.

Open Platform Examples:

SMM tip presented at Numerical Electromagnetic

European Standard:
IEC 61189-2-721:2015
CEN-CENELEC Workshop 2021

QWED

On our 25th anniversary, 10 May 2022

See us at the American Day of Karta Foundation, POLIN Museum

Annually at IEEE IMS

See us on 21-23 June 2022:

IMS Connecting Minds. Exchanging Ideas.

EXPLORE THE PEAKS OF MICROWAVE ENGINEERING DENVER2022

Biannually at MRW

See us on 12-14 September 2022:

Microwave and Radar Week MRW 2022

info@qwed.eu

www.qwed.eu