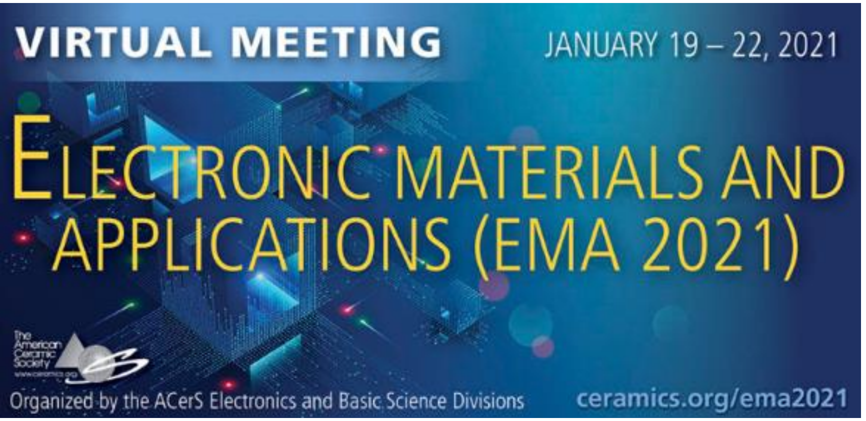


VIRTUAL MEETING JANUARY 19 – 22, 2021

ELECTRONIC MATERIALS AND APPLICATIONS (EMA 2021)

Organized by the ACerS Electronics and Basic Science Divisions ceramics.org/ema2021

How to support 5G materials measurements, antenna designs, and standards developments with QuickWave simulations

Malgorzata Celuch*, Marzena Olszewska–Placha*, Janusz Rudnicki
QWED Sp. z o.o., Warsaw, Poland

S13 – 5G Materials and Applications Telecommunications 22 Jan 2021

Outline

1. Electromagnetic modelling & simulations – development & applications by QWED.

2. Modelling-based characterisation techniques for 5G materials.

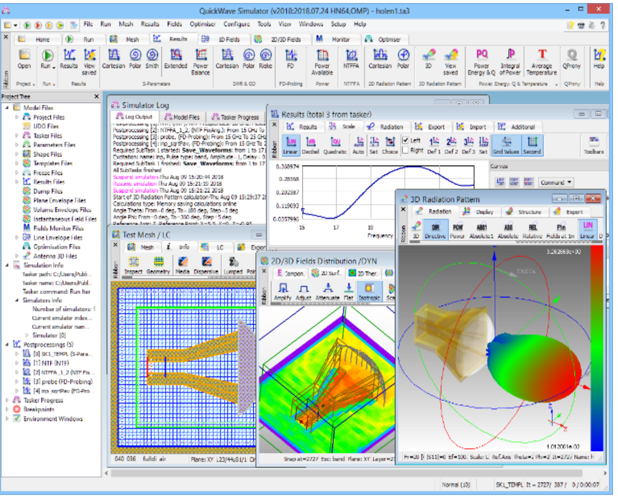
3. Electromagnetic design of 5G antennas.

4. Modelling of mm-wave interactions with tissues (for standards' developments).

5. Conclusions & outlook.

Polish high-tech SME - 23 years on the world's market

Business branches *presented annually at IEEE IMS Show*



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

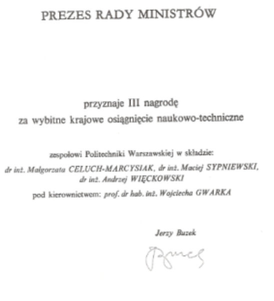
based on 300+ publications by:

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

dr.M.Celuch, President of QWED

THE EUROPEAN INFORMATION TECHNOLOGY PRIZE *Winner*

MISTRZ TECHNIKI WARSZAWA



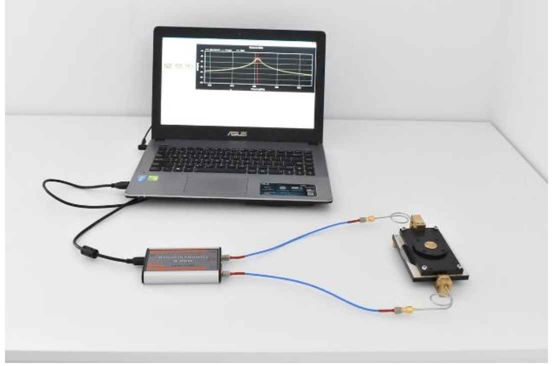
PREZES RADY MINISTRÓW

przyznaje III nagrodę
za wybitne krajowe osiągnięcie naukowo-techniczne

zespołowi Politechniki Warszawskiej w składzie:
dr inż. Małgorzata CELUCH-MARCYSIAK, dr inż. Maciej SYPNIEWSKI, dr inż. Andrzej WIĘCKOWSKI
pod kierownictwem: *prof. dr hab. inż. Wojciecha GWARKA*

Jerzy Buzek

Warszawa, 1 grudnia 1999 roku



Test-fixtures for precise material measurements

based on 300+ publications

by prof.J.Krupka, IEEE Fellow

DIPLOMA

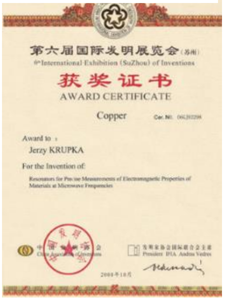
Eureka!

THE BELGIAN AND INTERNATIONAL TRADE FAIR FOR TECHNOLOGICAL INNOVATION

Jerzy KRUPKA

Résonateurs pour des mesures précises des propriétés électromagnétiques de matériaux à bande de fréquence micro-ondes.

Médaille d'or



第六届国际发明展览会（苏州）

6th International Exhibition (SuZhou) of Inventions

获 奖 证 书

AWARD CERTIFICATE

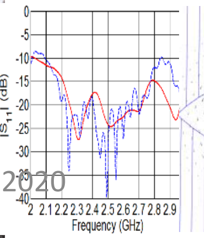
Copper

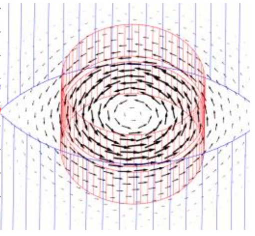
Award to :

Jerzy KRUPKA

For the Invention of:

Resonators for Precise Measurements of Electromagnetic Properties of Materials at Microwave Frequencies





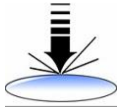
Consultancy & design services based on EM expertise & tools

team of 10+engineers, 4 PhDs, 2 Profs

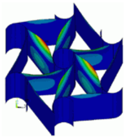
key areas: MW power appliances,

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) – accelerating the development of high efficiency solar cells through application and enhancement of material measurement techniques

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.

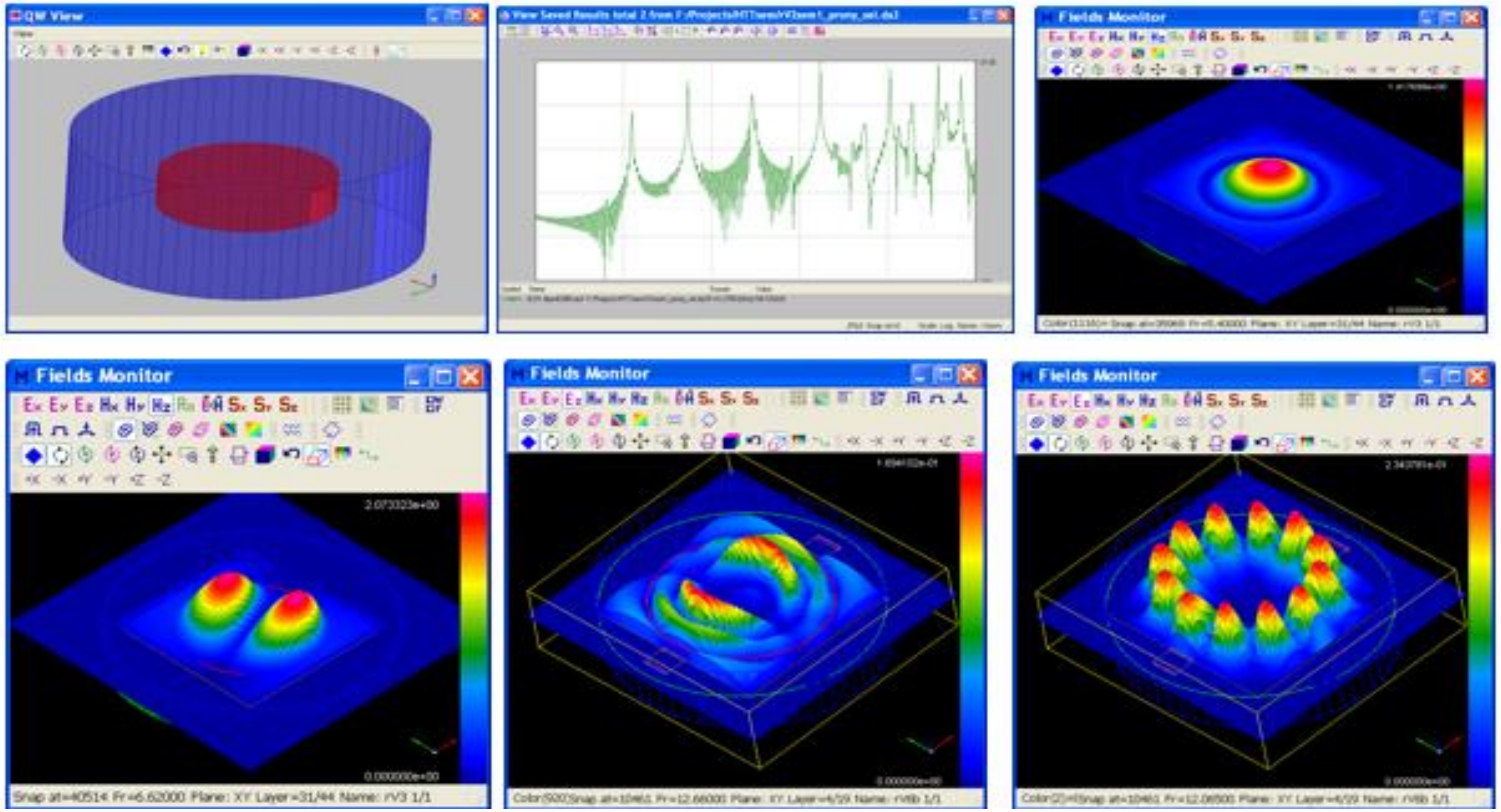
Modelling – based characterisation of 5G materials

Focus on dielectric resonators:

- proven ultra-high acccuracy in GHz range (0.3% for Dk, IEC 61189-2-721:2015)
- dedicated to low-loss materials & thin material sheets
- ease-of-use
- available on the market
- repeatability & reproducibility for 5G under independent studies (iNEMI project)

How do dielectric resonators work

Dielectric resonator *(top left)*
as a multimode device *(see transmission diagramme, top centre)*
including TE01 mode *(top right)* **and many higher modes** *(lower row)*

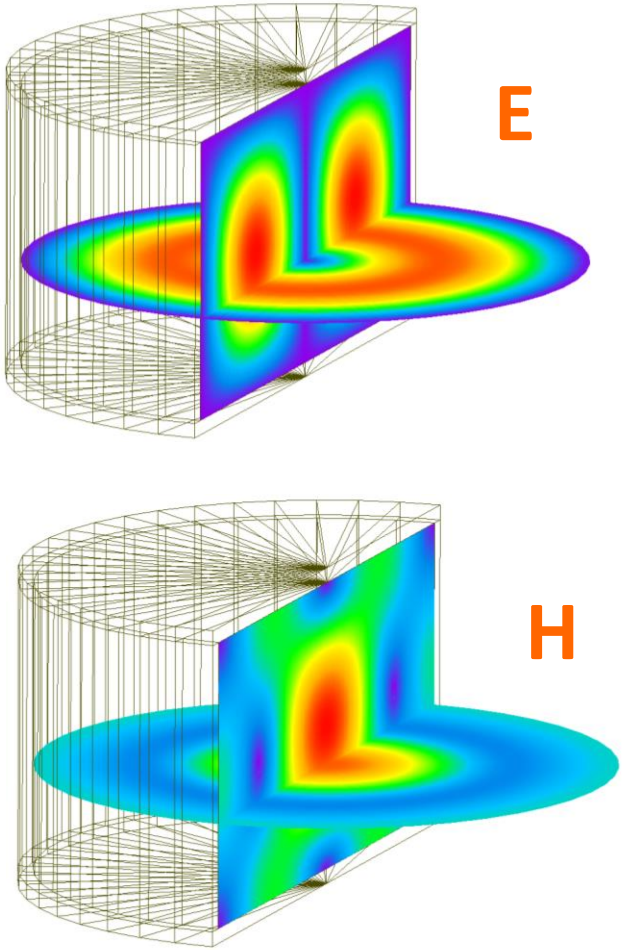


What is RESONANCE

Eigenvalue problem in theoretical electromagnetics:

- Non-zero electromagnetic fields (non-zero energy) exist in a region without any energy exchange with the outside (no "feeding").
- This is mathematically possible at specific frequencies (eigenfrequencies). The corresponding spatial field patterns are called modes (eigenmodes).
- In a lossless region, the fields exists ("ring") *ad infinitum* (sinusoidal oscillations).
- If there are (not-too-high) losses in the region, the fields are gradually damped (damped sinusoidal oscillations) with damping characterised by quality factor (Q-factor) and frequency little alterated (compared to the same materials with losses neglected).

Example: TE011 mode in cylindrical cavity

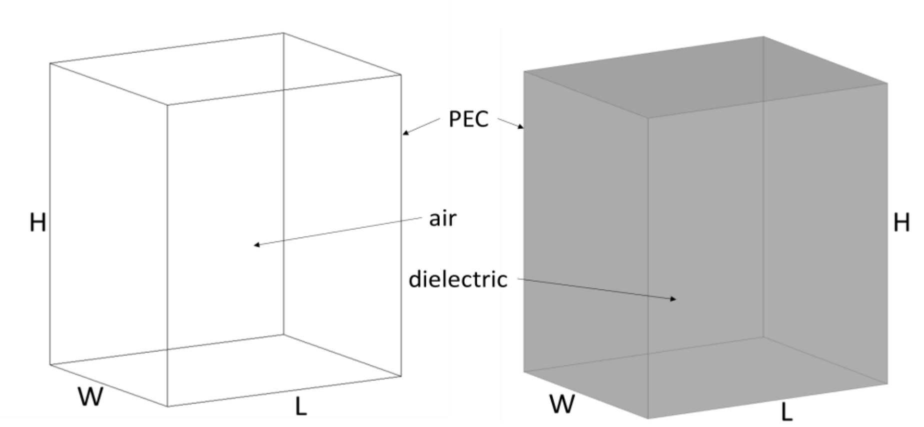


Resonance problem in applied electromagnetics:

- There is feeding from the outside, but the coupling is non-too-strong.
- The corresponding resonant frequencies are close to eigenfrequencies of the corresponding isolated problem.
- Energy loss in a lossy resonating region is compensated with energy supplied by the feed. Energy is also lost on internal losses (resistance) of the feed.

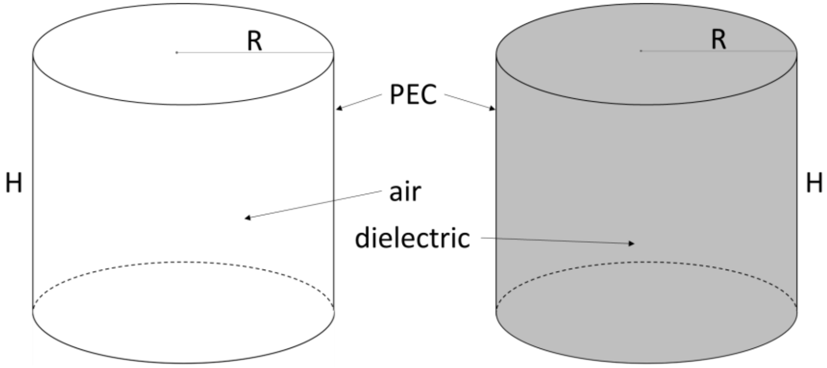
Canonical examples of resonators

Eigenvalue problems: analytical solutions exist for cuboidal and cylindrical cavities:



$$Q = 2\pi \frac{\overline{W}}{\overline{P}_q T}$$

$$Q = 2\pi \frac{\iiint_V \varepsilon \vec{E} \cdot \vec{E}^* dv}{T \iiint_V \sigma \vec{E} \cdot \vec{E}^* dv} = \frac{\omega\varepsilon}{\sigma} = \frac{1}{\tan\delta}$$

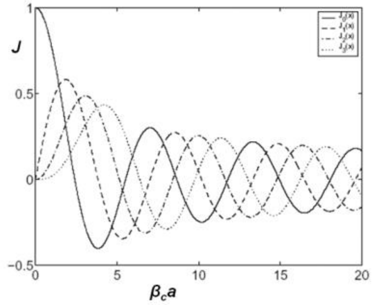


in non-magnetic low-loss dielectrics

$$f_{r,mnp} = \frac{v}{2}\sqrt{\left(\frac{m}{W}\right)^2 + \left(\frac{n}{L}\right)^2 + \left(\frac{p}{H}\right)^2}$$

$$v = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{c}{\sqrt{\varepsilon_r}}$$

$$f_{r,mnp} = \frac{v}{2}\sqrt{\left(\frac{\kappa_{mn}^{(,)}}{\pi R}\right)^2 + \left(\frac{p}{H}\right)^2}$$

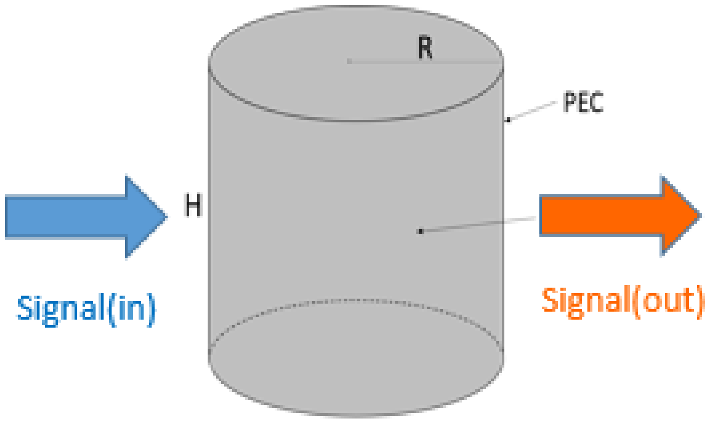


→ application of cavities to Dk measurements appears straightforward!

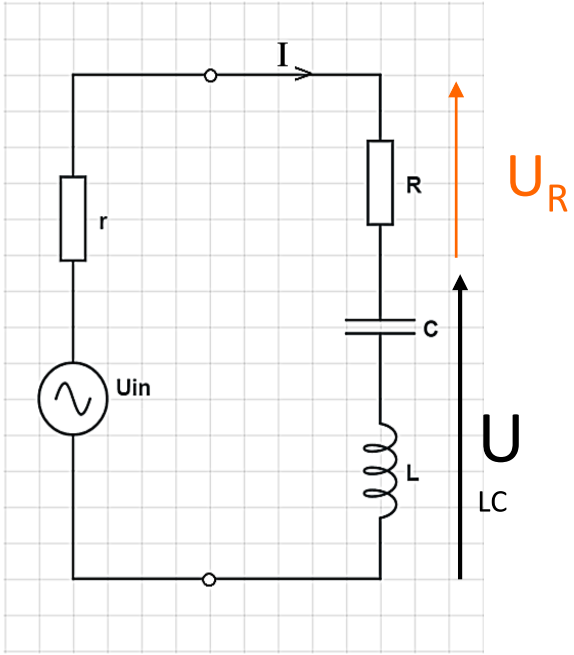
(but cavity losses should be minimised)

Canonical examples of resonators

Analytical solutions are for eigenvalue problems.
Measurement problems are deterministic (cavity is coupled to source & load).



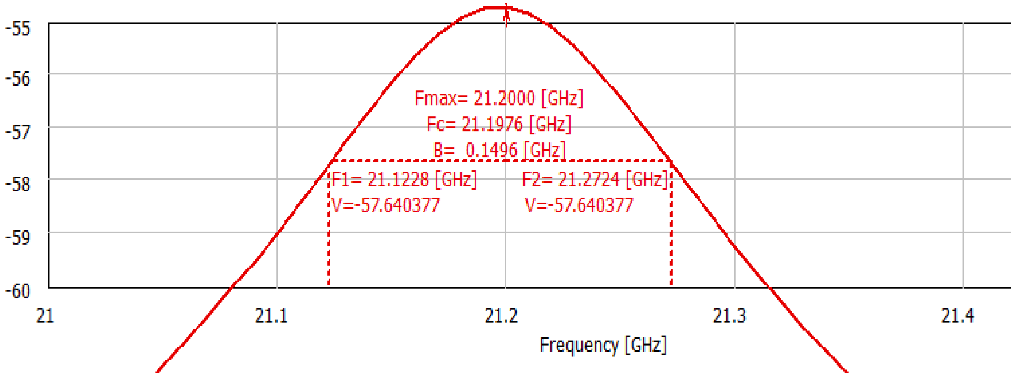
given fixed strength of Signal(in),
at resonance Signal (out) is strongest

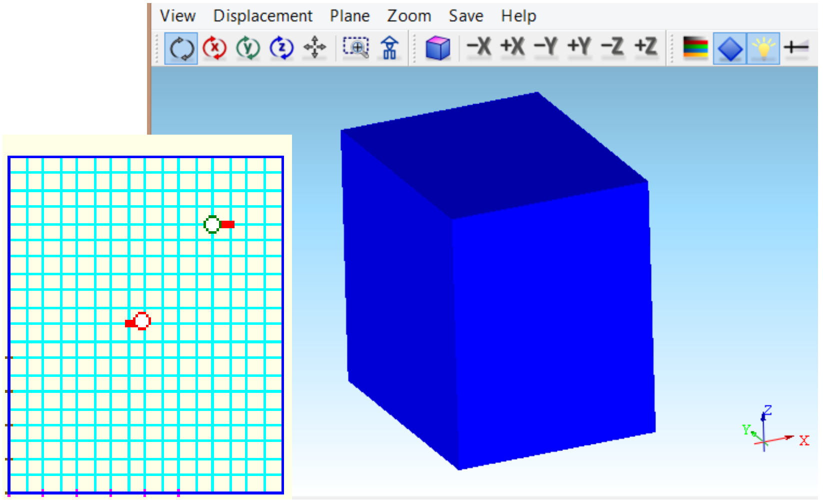


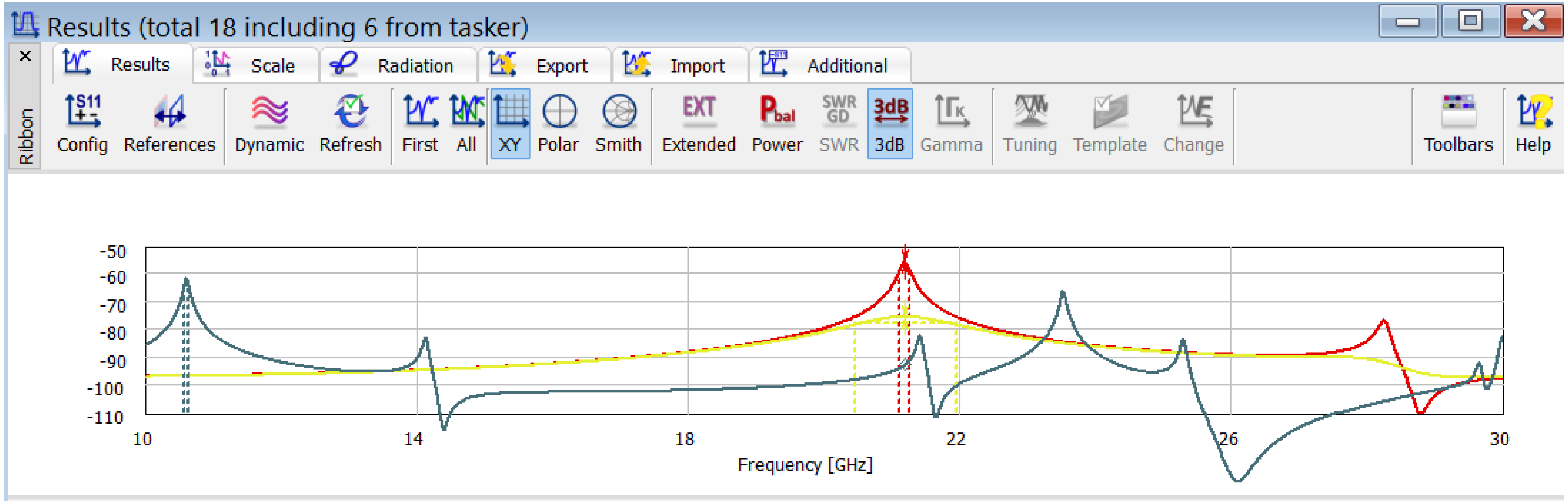
given fixed strength of Uin,
at resonance U_R is strongest (U_{LC} =zero)

QuickWave model of a cuboidal cavity

Transmission |S21| simulated between weakly coupled source and probe in a cube 8x10x10 [mm]







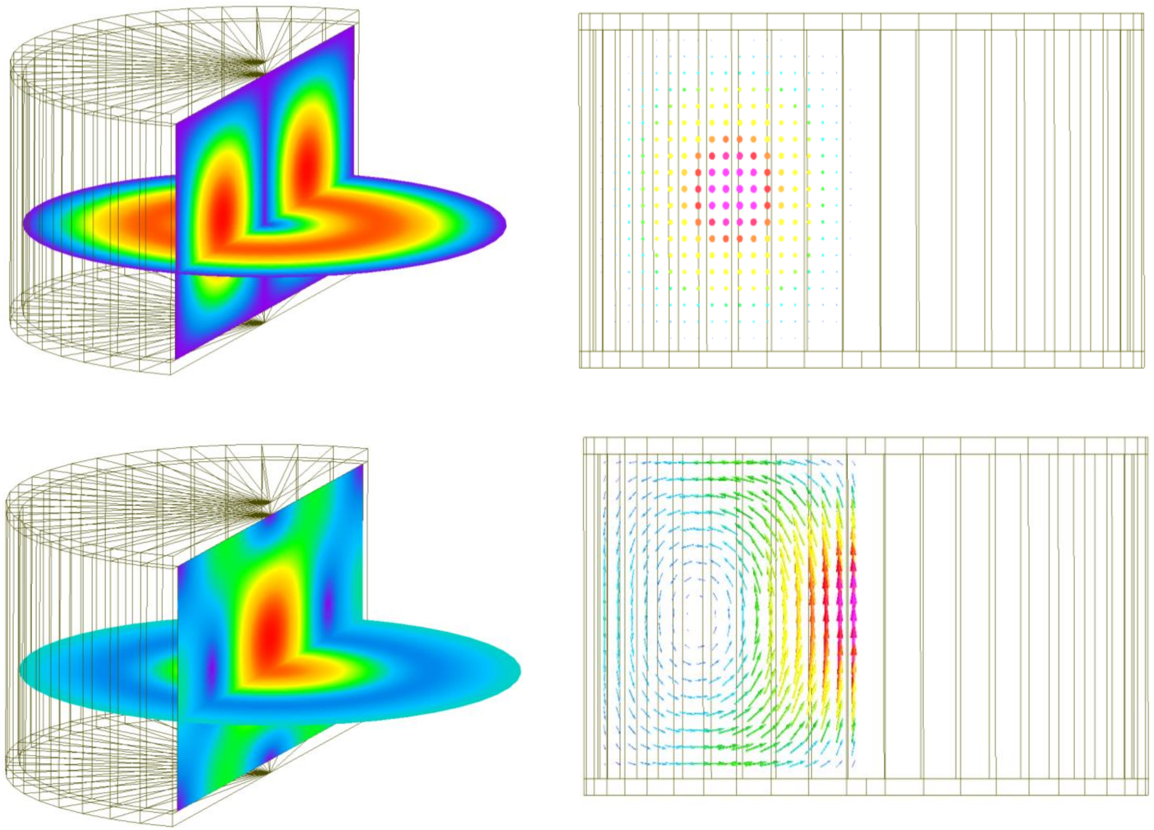
ε_r=1 σ=0.00833 S/m @21.2GHz:
tanδ=0.071
Q_{SUT}= 1 / 0.0071 = 141
Q_{S21}=21.2/0/1496= 141

ε_r=1 σ=0.0833 S/m

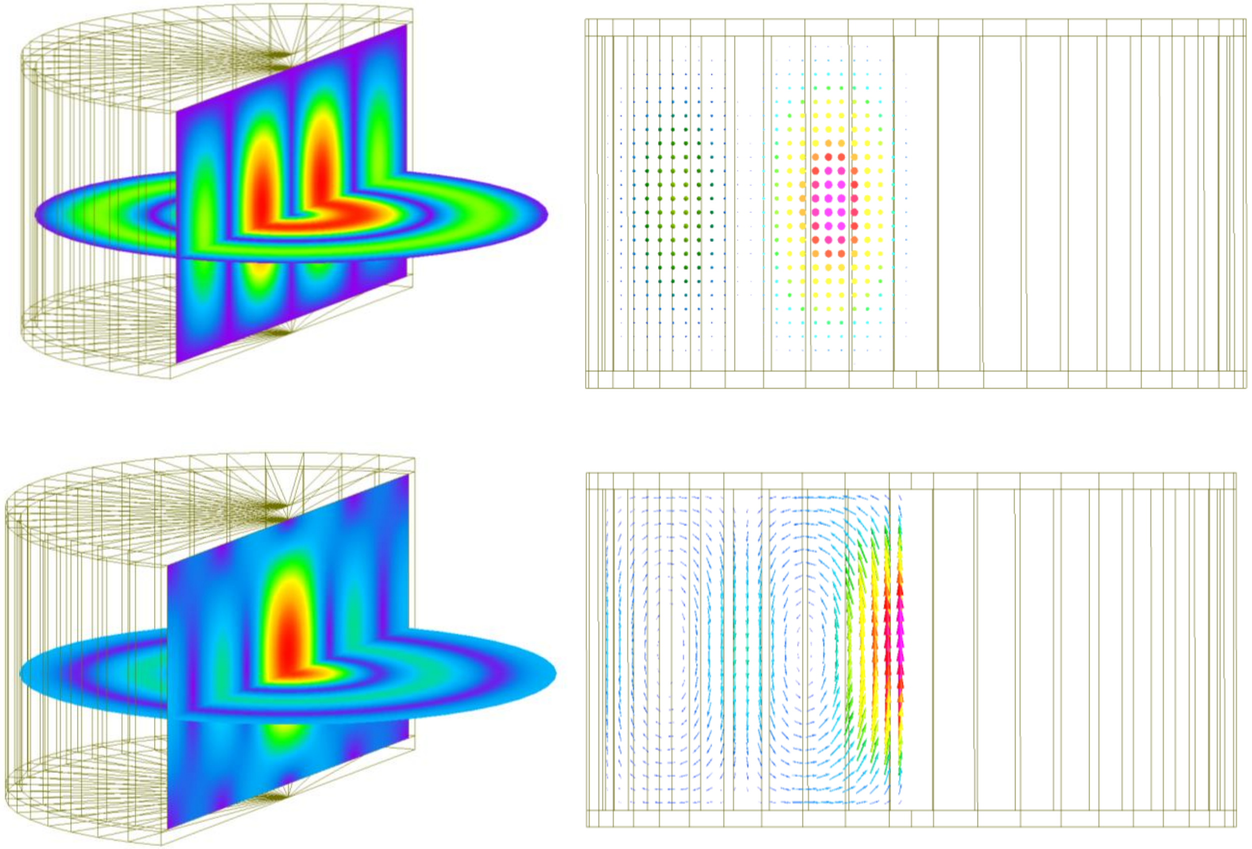
ε_r=4 σ=0.0166 S/m

QuickWave model of a cylindrical cavity

TM011 mode



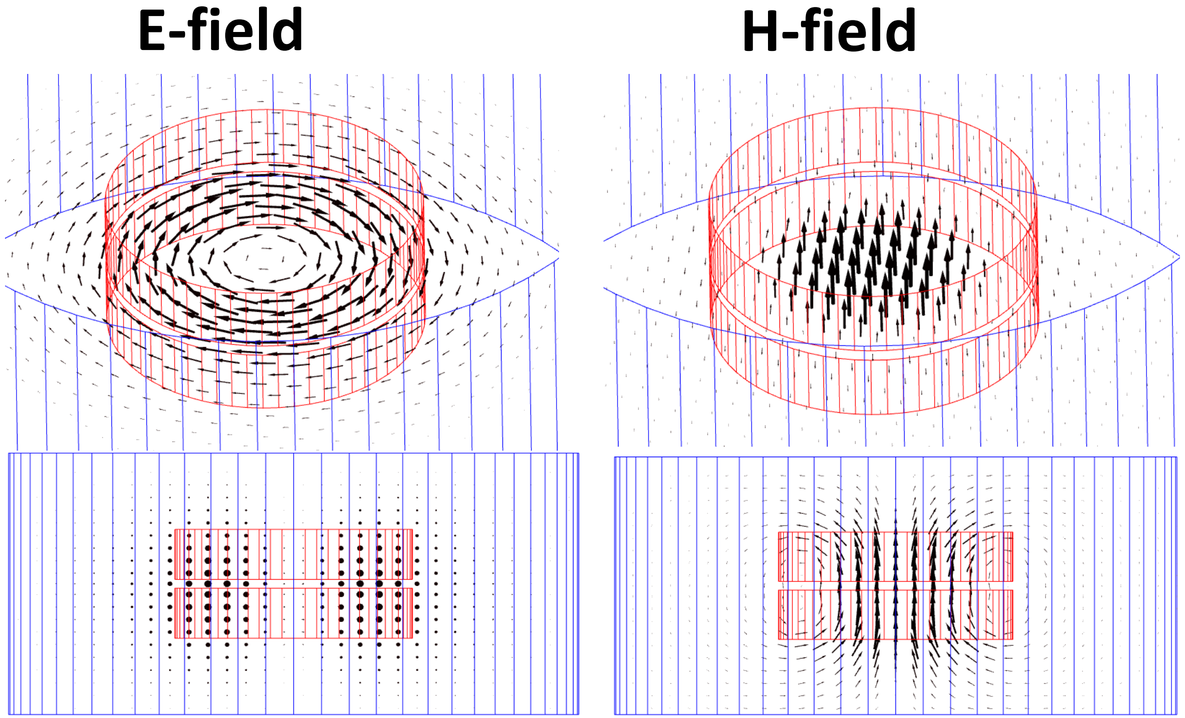
TM021 mode

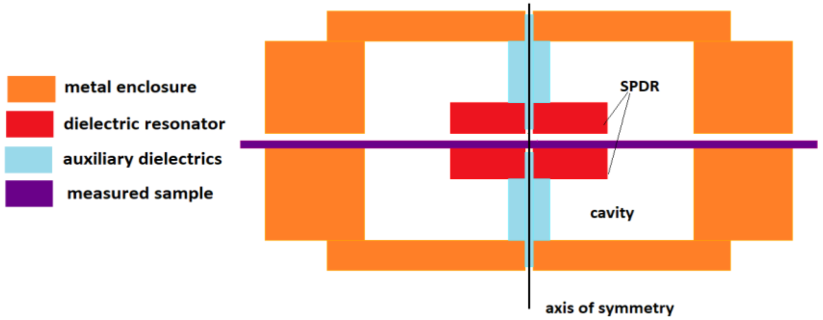


compared to rectangular (cuboidal) cavities, typically:

- lower contribution of wall losses
- easier standard manufacturing

Split-Post Dielectric Resonator method





- resonant mode with EM fields mostly confined in and between those ceramic posts → minimial losses in metal enclosure
- H-field is only vertical at the side wall of the enclosure → only circumferential currents in side wall → no radiation through slot
- E-field tangential to SUT → air slots between SUT and posts have negligible effect
- **easy SUT insertion through slot, no dismatling, NDT method**
- all EM energy injected through the coupling loops in contained within in the SPDR “head” (inside the enclosure)
- an estimated 95% of energy confined in and between the ceramic posts
- **once-in-a-lifetime calibration suficient for general materials (NOTE: new calibration services dedicated to 5G coming soon!)**

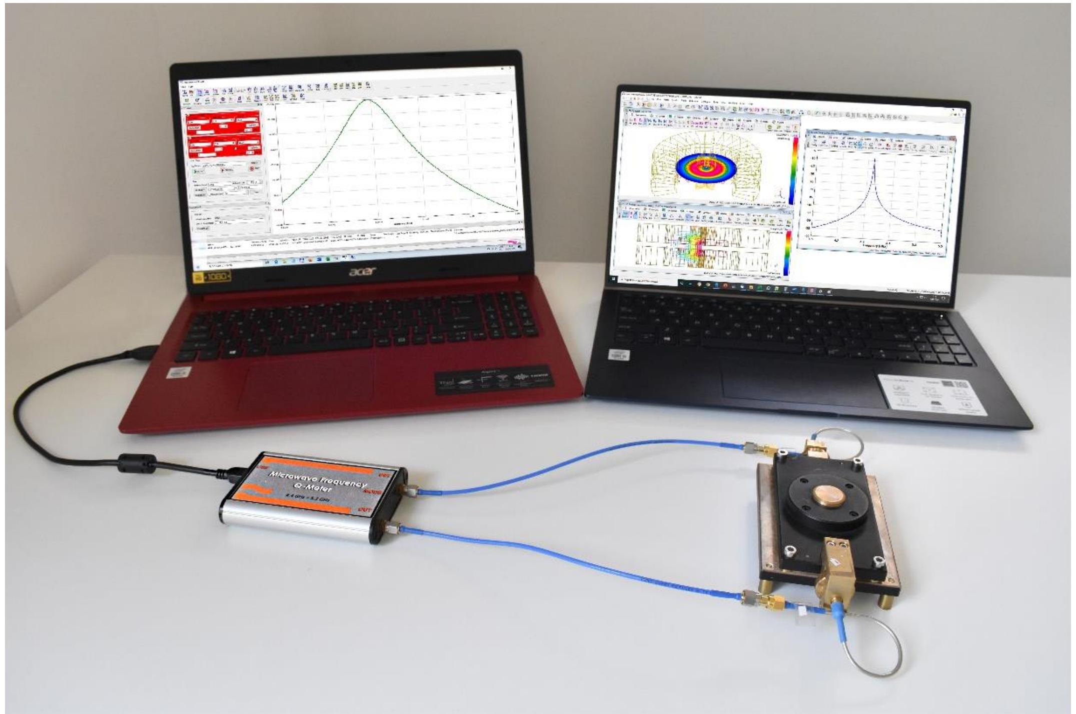
Split-Post Dielectric Resonator method

SUT of $\varepsilon_s = \varepsilon_s' - j\,\varepsilon_s''$ is inserted into DR:
resonant frequency changes from f_e to f_s
Q-factor changes from Q_e to Q_s.

$$\frac{f_e - f_s}{f_e} \approx \frac{h}{2C}\iint_S \left[\varepsilon_s'(x,y)-1\right]\left|E(x,y)\right|^2 dS$$

$$\frac{1}{Q_s}-\frac{1}{Q_e}\approx\frac{h}{C}\iint_S \varepsilon_s''(x,y)\,E^2(x,y)\,dS$$

$$C=\iiint_V \left|E(x,y)\right|^2 dV$$

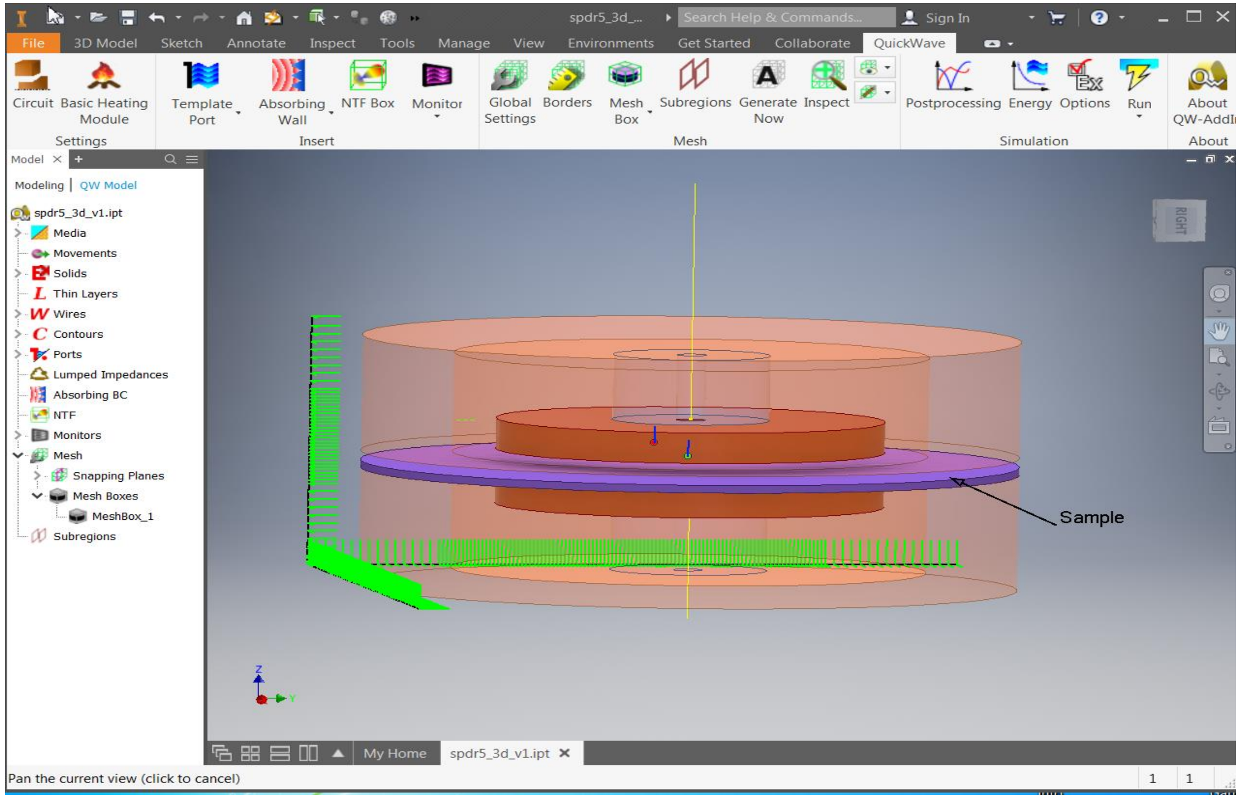


field assumed invariant in *z*-direction
S is called the DR's *head*
sign ≈ reflects field patern changes caused by SUT

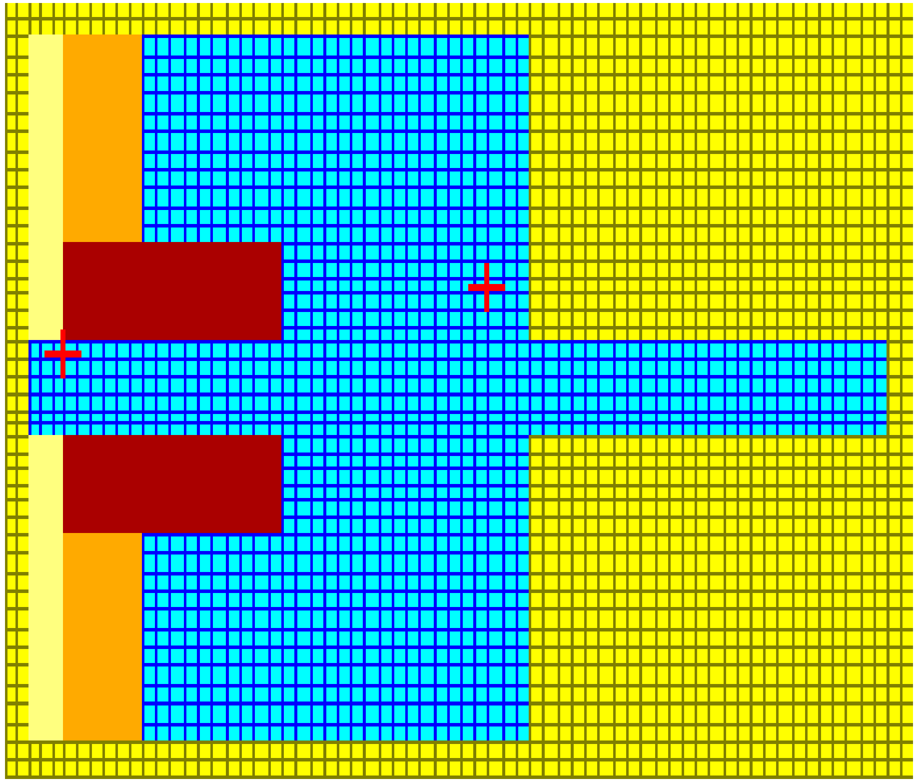
calibration (based on modelling)
minimises efects of:

field variation in *z*
field changes due to SUT
manufacturing tolerances

QuickWave modelling of SPDR



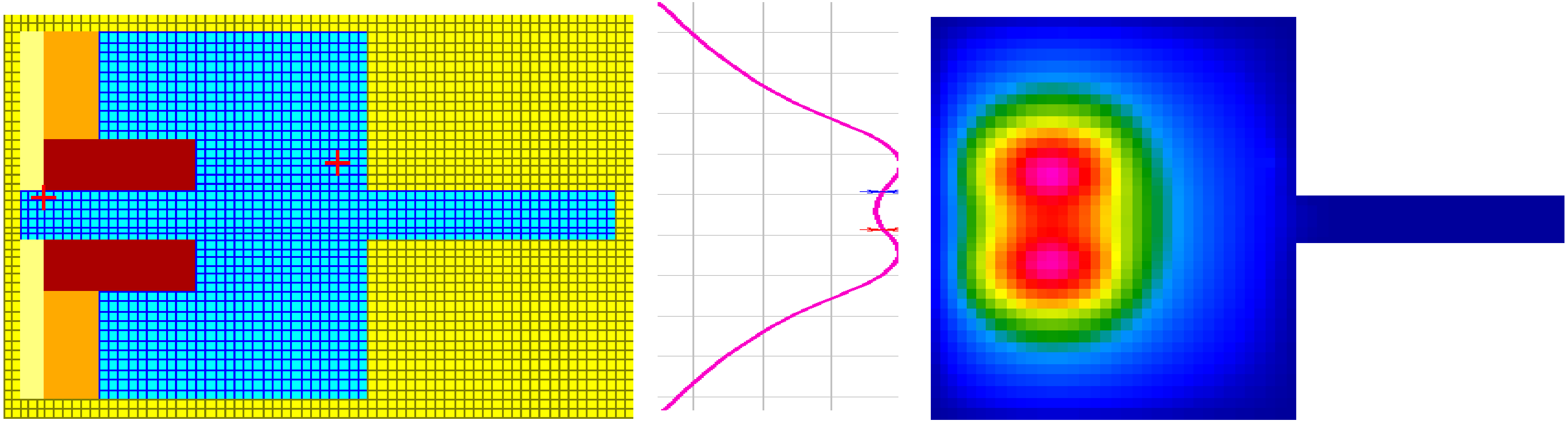
Pan the current view (click to cancel)



Full 3D model of 10GHz SPDR
in QW-AddIn for Autodesk® Inventor® Software
(common environment for modelling & manufacturing)

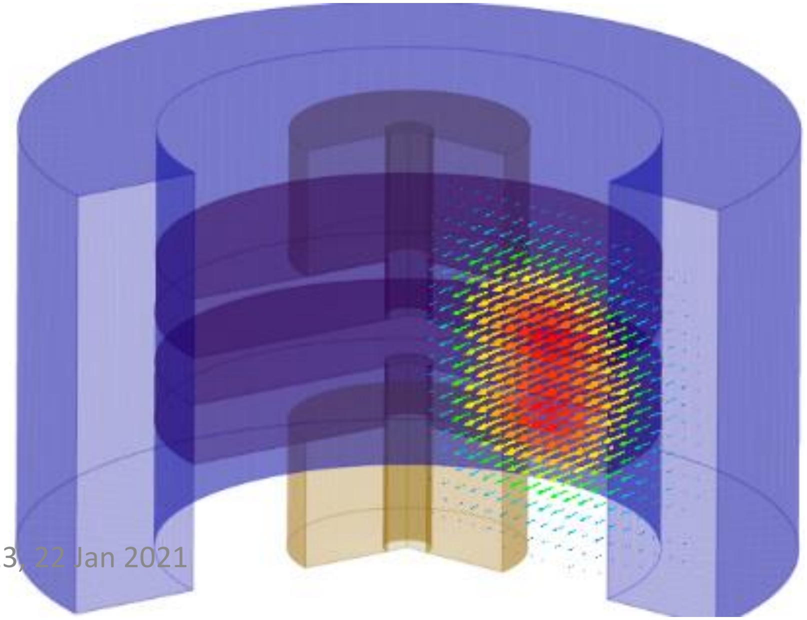
Axisymmetrical 2D BOR model
full EM information
economies in computer effort : 10^3 or more

QuickWave model of SPDR field distribution

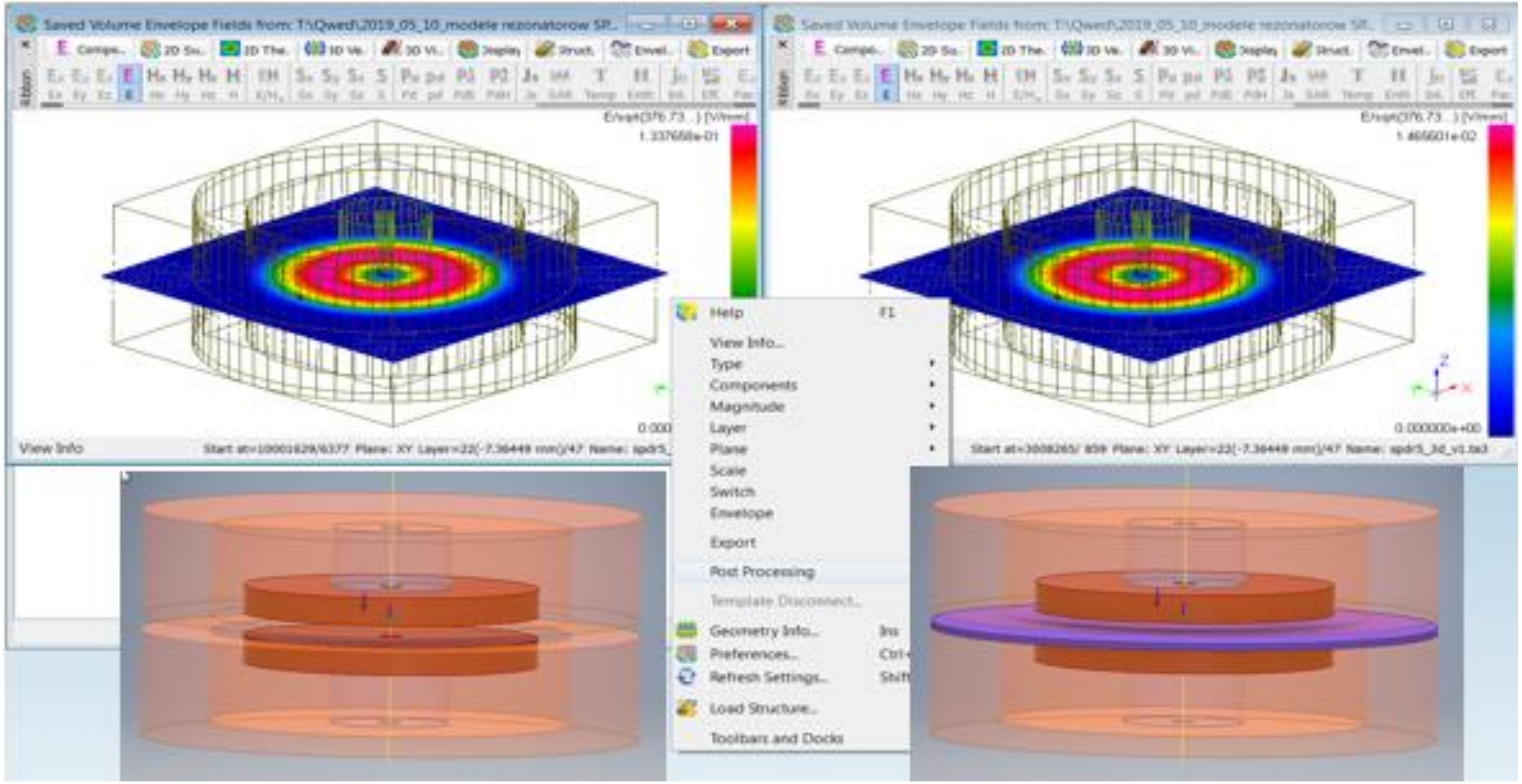


Sample in strong E-field nearly constant between the two posts

- applicable to thin sheets
- low sensitivity to sample positioning along the height of the slot



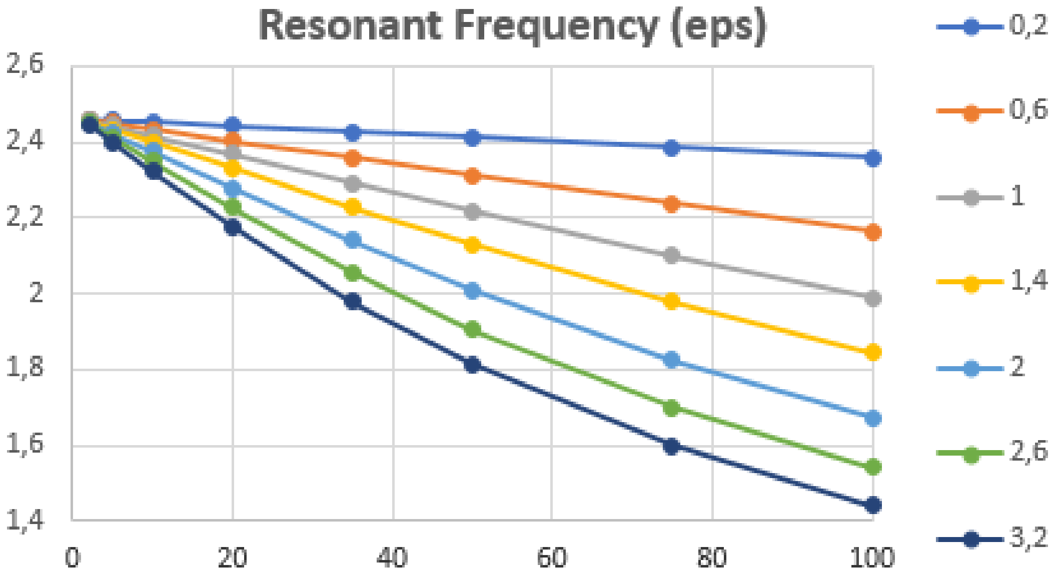
QuickWave model for SPDR loaded with sample

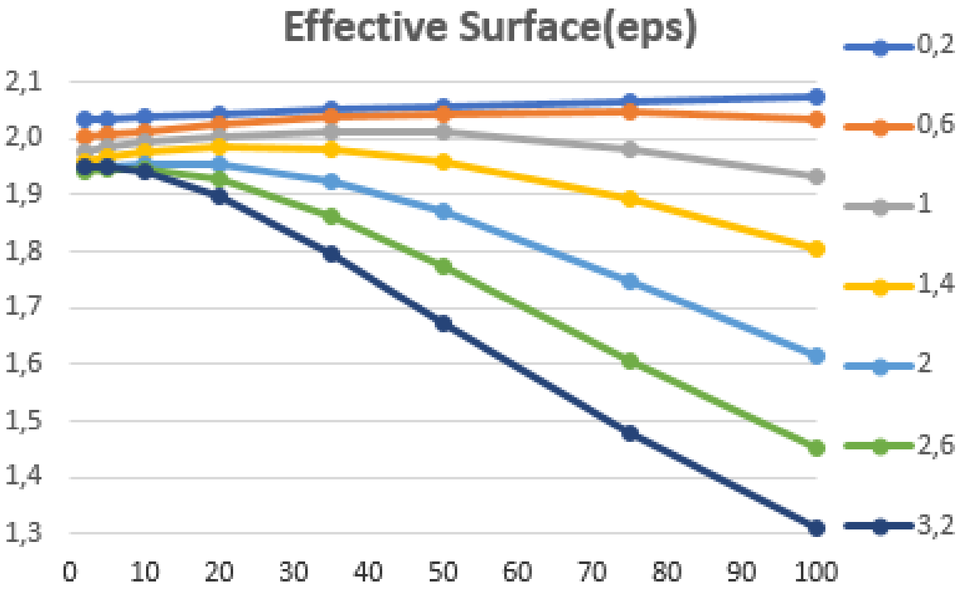


Field patterns remain practically unchanged
by resonant frequencies and Q-factors change,
providing information about SUT material parameters

QuickWave model for SPDR loaded with sample

QuickWave simulations of 2.5GHz SPDR performed in automatic Parameter Sweep for varying sample thickness (colours) and dielectric constant (eps)

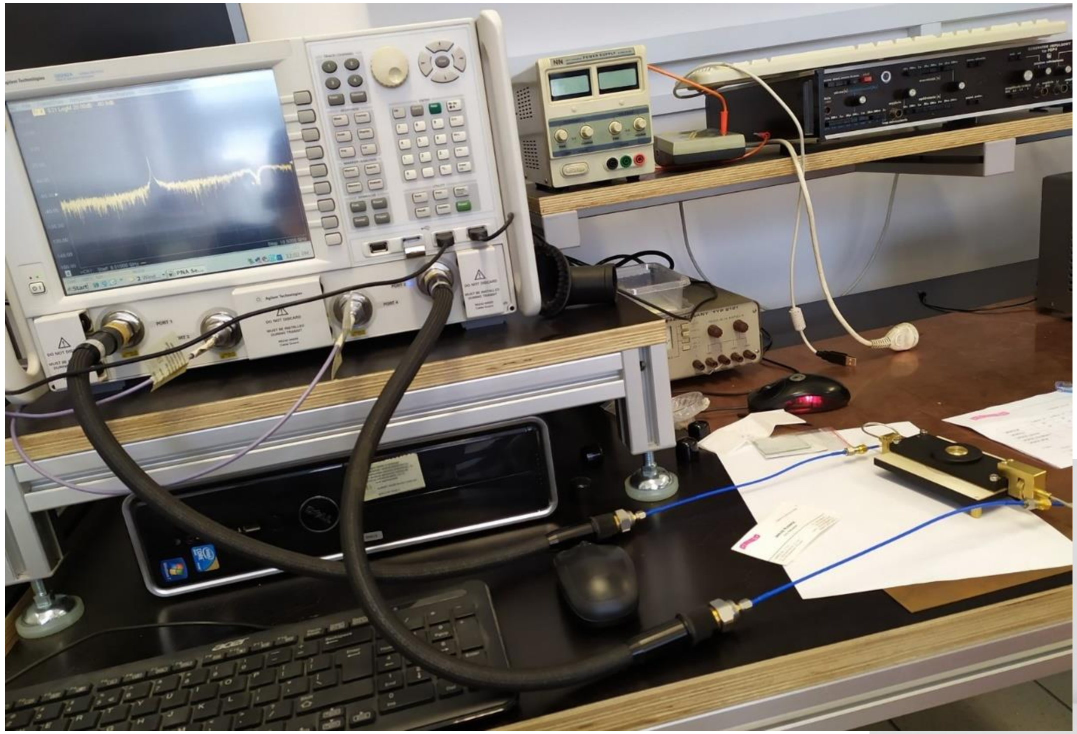




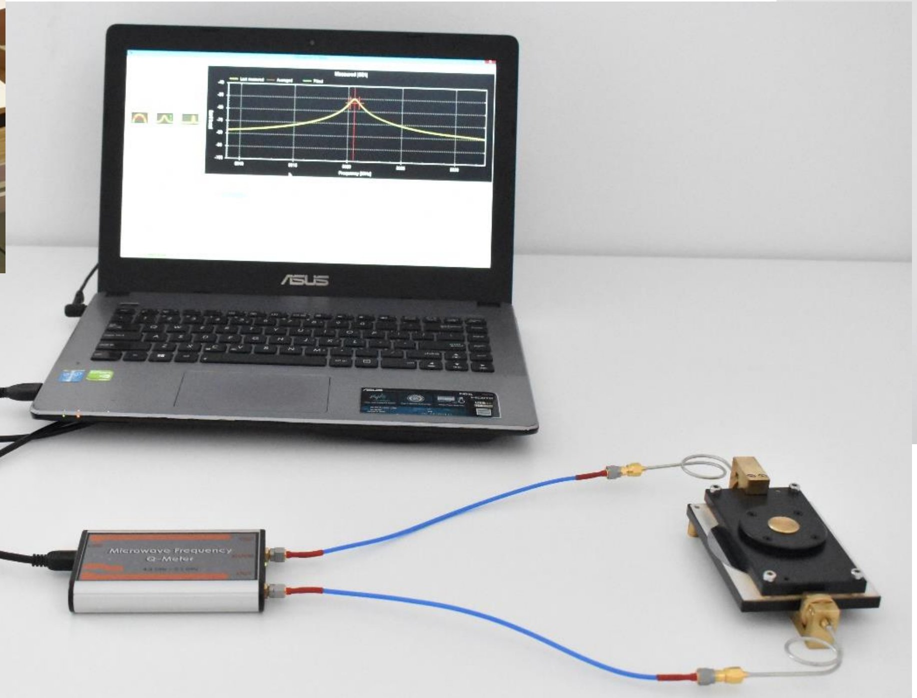
resonant freq. changes are nonlinear
(simple perturbation eqs. are not accurate enough)

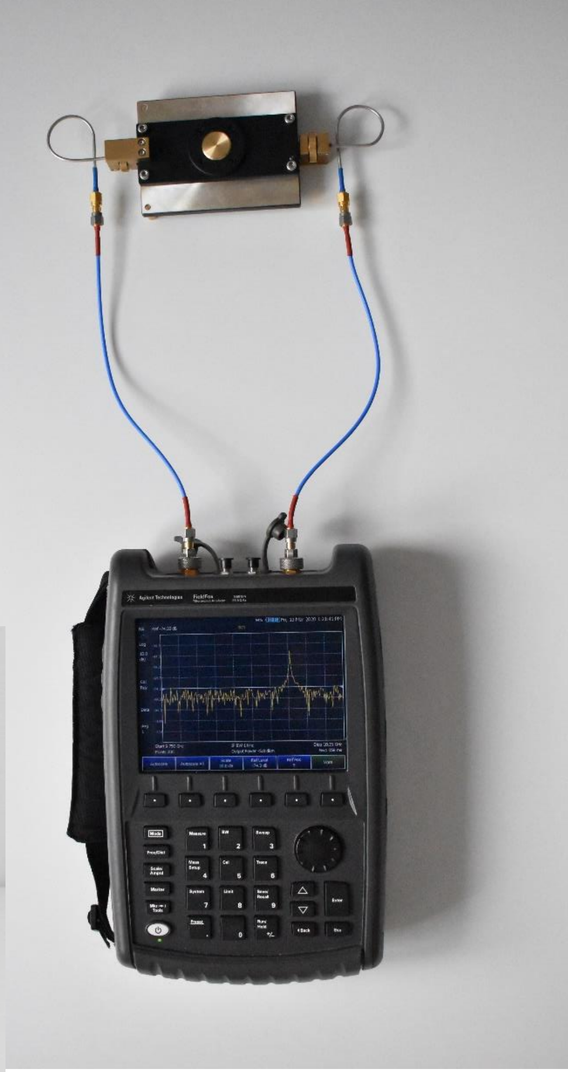
intermediate parameter is defined
leading to slowly-varying functions
tuned in calibration

SPDR use in big & small labs...



...and at home



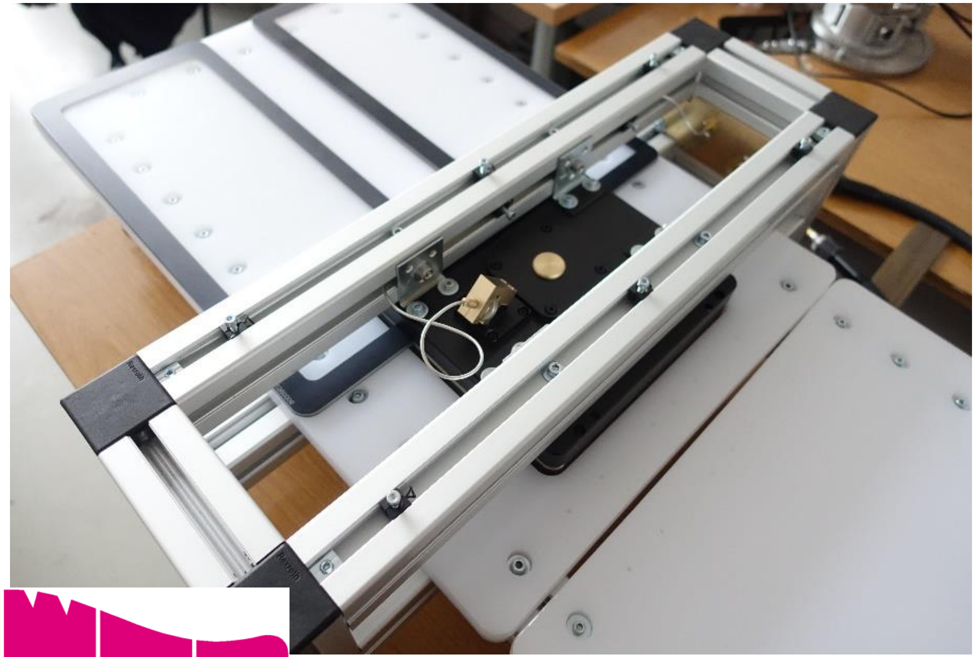


Surface scanning with SPDR

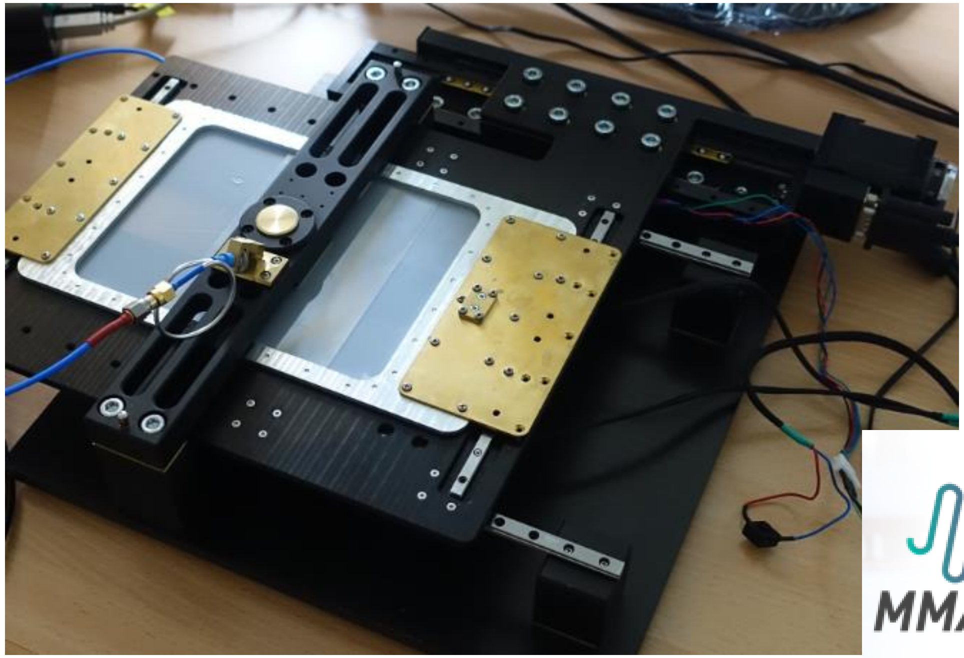
Obviating the limitations:

- SUT lateral min size ("absolute" EM constraint) - 14..120 mm → scanning & postprocessing
- spatial resolution 14..120 mm → scanning & postprocessing
- SUT lateral max size – 40..150 mm → increase by change of mechanical construction

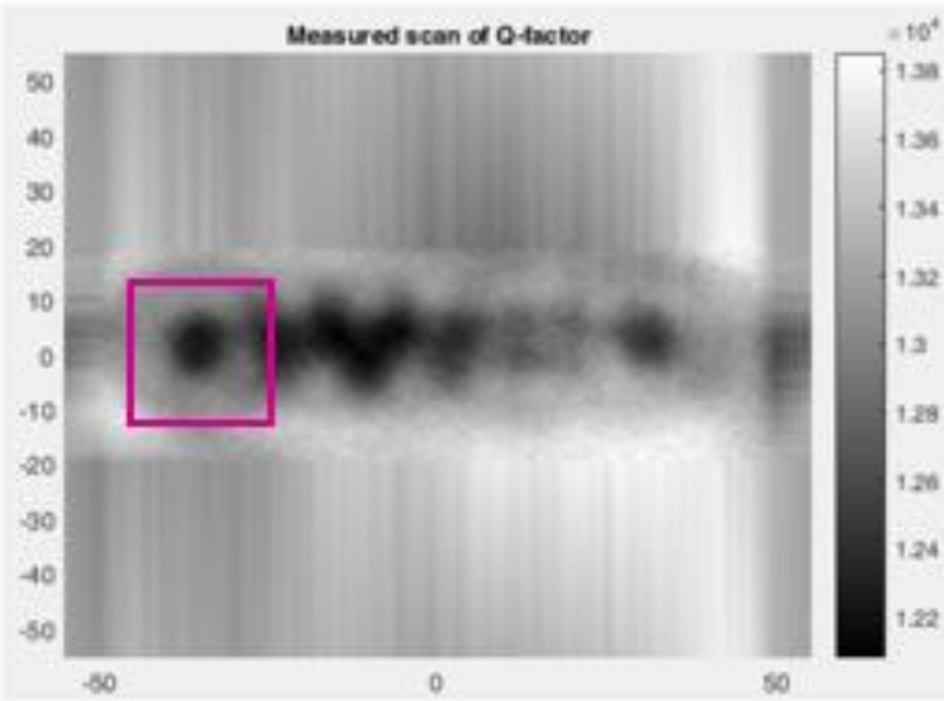
manual scanner for large panes of glass
(MW oven window)



automatic scanner
semiconductor wafers, composites, ceramics



Surface scanning with SPDR & resolution enhancement



sample resistivity (measured Q-Factor)
scan with QWED 10GHz SPDR scanner
in H2020MMAMA project

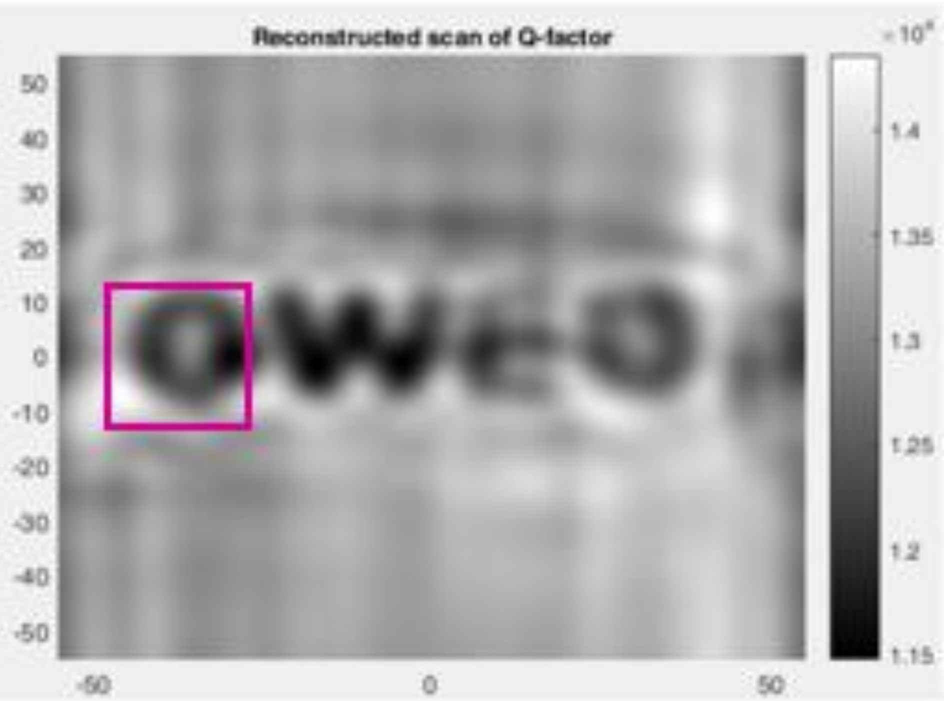
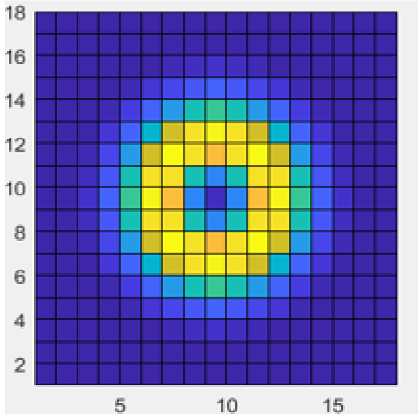
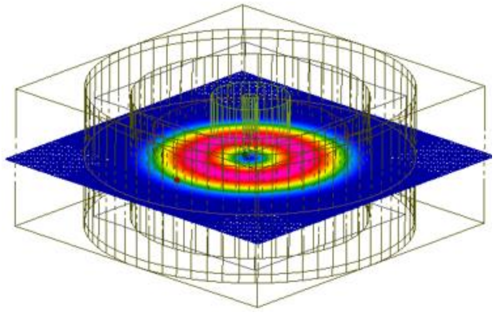


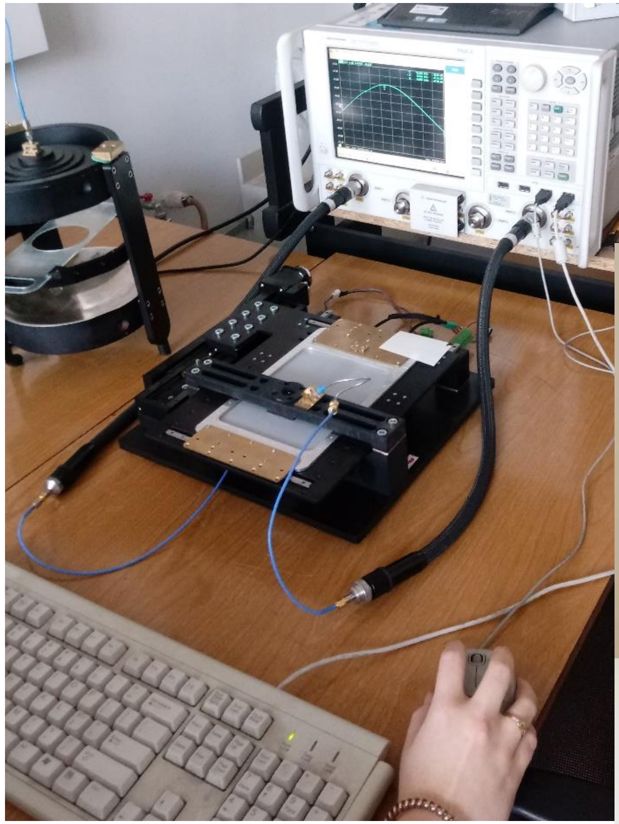
image post-processed
using SPDR field pattern
simulated in QuickWave

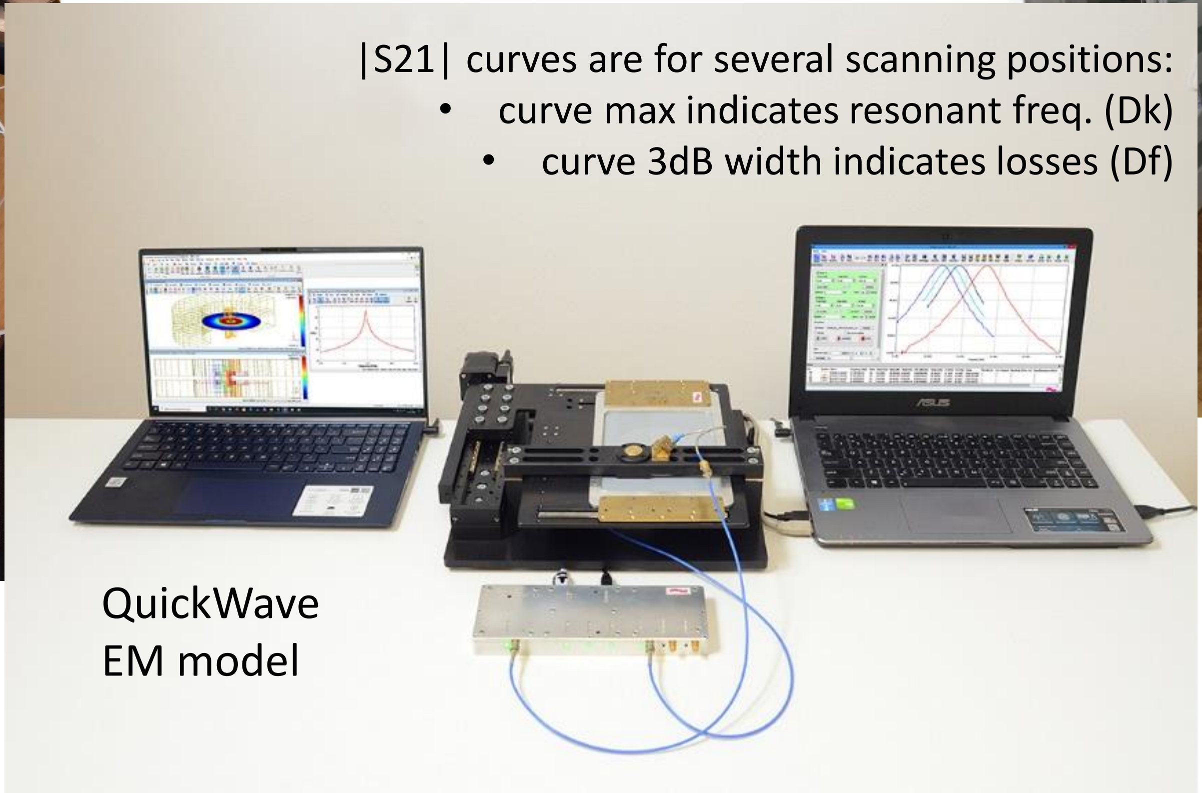




Patterned PEDOT:PSS sample courtesy MateriaNova, Belgium

SPDR incorporated in 2D scanner (for surface non-uniformities)

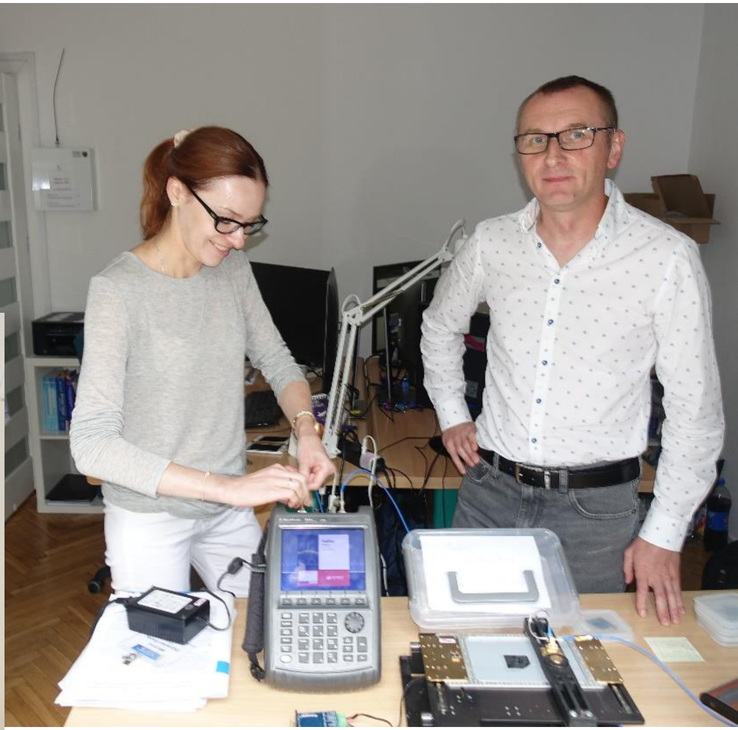




|S21| curves are for several scanning positions:

- curve max indicates resonant freq. (Dk)
- curve 3dB width indicates losses (Df)

QuickWave
EM model



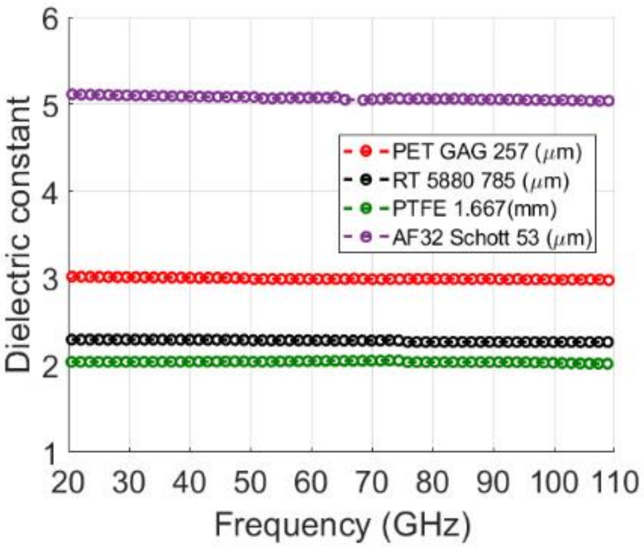
**A joint product of QWED and Keysight,
developed in the H2020 MMAMA project,
has been acknowledged as
Innovation Radar
of the European research.
It is also marked as
#Women led innovation**

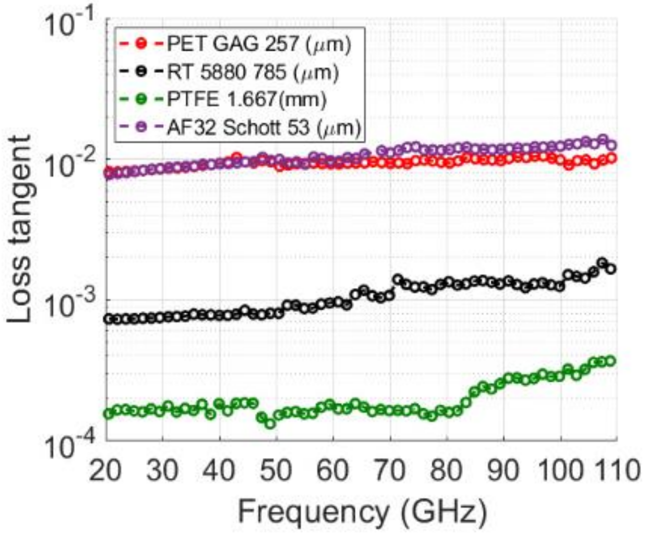
https://www.innoradar.eu/resultbykeyword/qwed

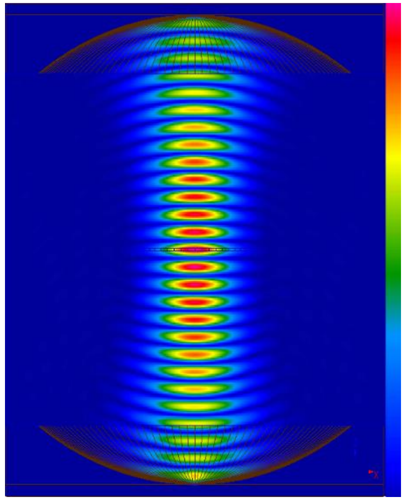
QuickWave design of mm-Wave resonators

- Standard SPDRs are provided for 1.1GHz – 15 GHz
- Custom designs feasible for 20 GHz, further limitation due to wavelength, manufacturing tolerances & losses
- Other resonator solutions (**FPOR, BCDR**) designed & recommended >15GHz

Fabry-Perot Open Resonator



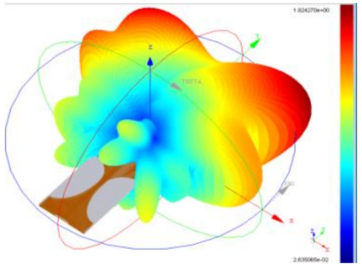




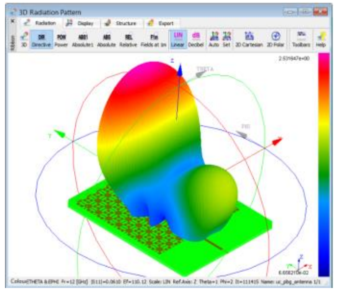
Fully automated wide-band multi-mode measurement: (10-15 min)

- Spectrum: 20-110 GHz
- Dk accuracy: $\Delta\varepsilon/\varepsilon < 0.5$ %
- Df range: $10^{-5} < \tan\delta < 10^{-2}$
- Sample diameter: > 3 inches
- Sample thickness: < 2 mm

Antenna & feed systems design – for various applications

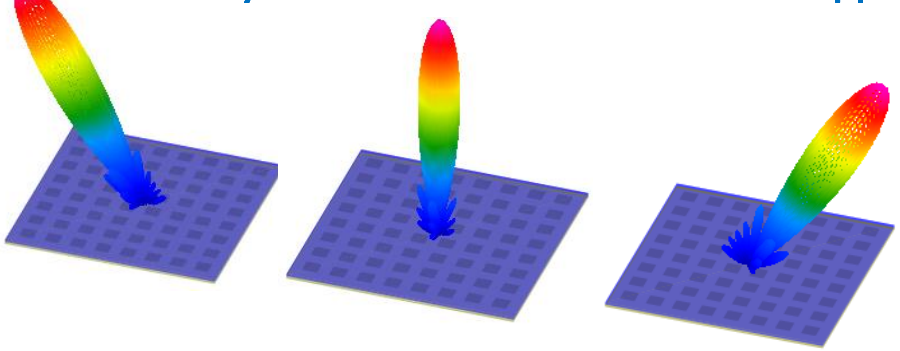


Balanced antipodal Vivaldi antenna & 3D radiation pattern at 10 GHz.

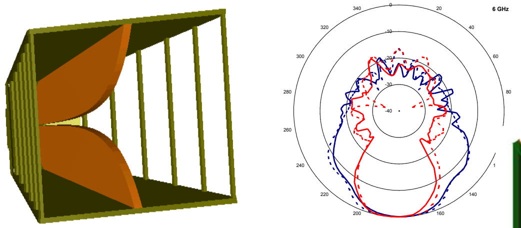


Aperture-coupled patch antenna on uniplanar photonic bandgap substrate & its radiation pattern at 12 GHz.

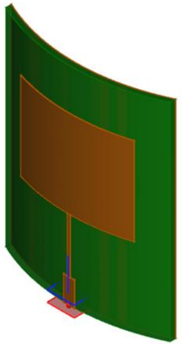
Antenna arrays for 5G and automotive radar application



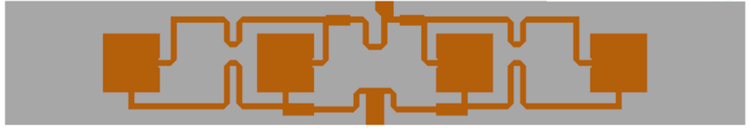
Designing and verifying tracking capabilities



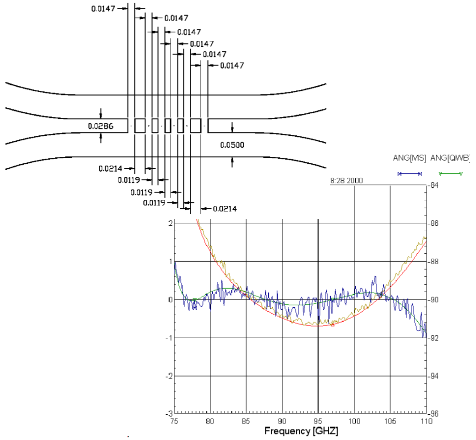
Pyramidal horn antenna for military surveillance measured (courtesy prof.B.Stec) & simulated patterns



Planar antennas for smart bio-sensors

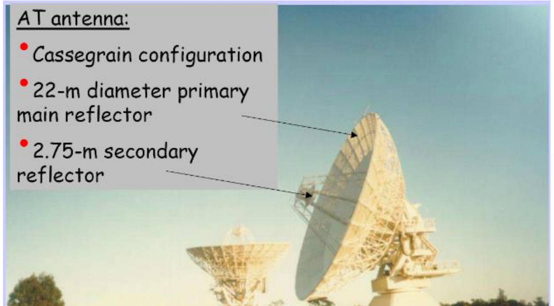


Antenna feed systems designed by NRAO

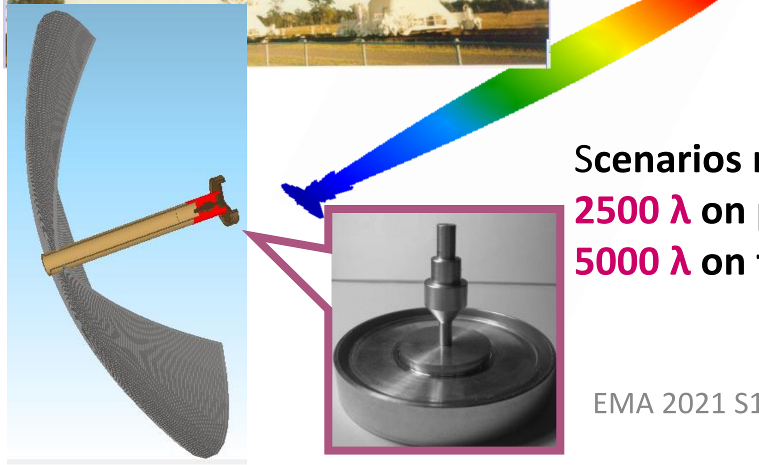


QuickWave 3D results at NRAO, see: ALMA Memos 381, 343, 325, 278.

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

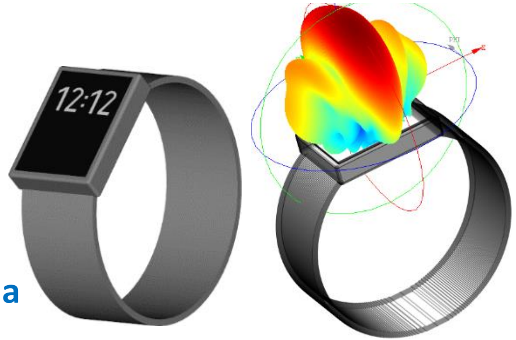


AT antenna:
- Cassegrain configuration
- 22-m diameter primary main reflector
- 2.75-m secondary reflector



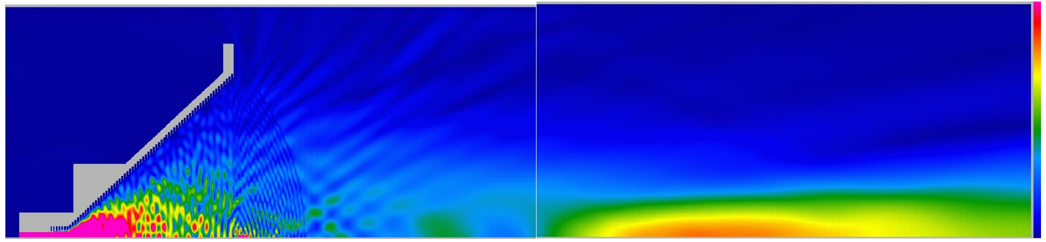
BOR FDTD

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



Smartwatch with embedded patch antenna

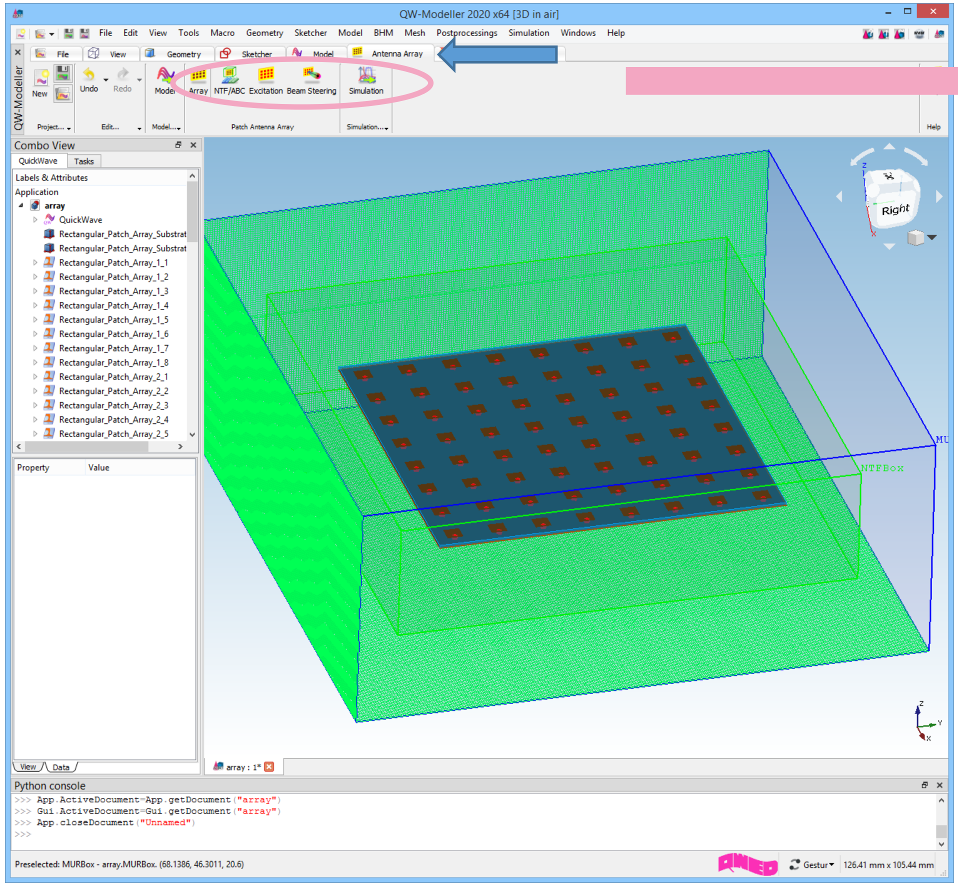
Scenarios modelled full-wave:
2500 λ on popular PC
5000 λ on top-shelf PC



Corrugated horn antenna for material measurements

Dedicated wizards for 5G patch antenna array project creation

QW-Modeller



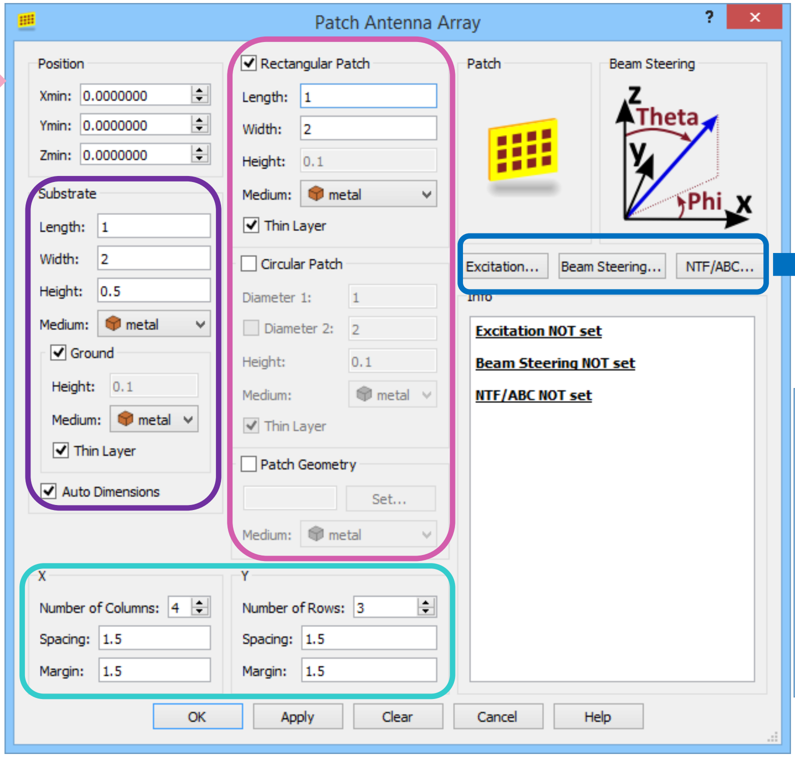
Application
- array
  - QuickWave
  - Rectangular_Patch_Array_Substrat
  - Rectangular_Patch_Array_Substrat
  - Rectangular_Patch_Array_1_1
  - Rectangular_Patch_Array_1_2
  - Rectangular_Patch_Array_1_3
  - Rectangular_Patch_Array_1_4
  - Rectangular_Patch_Array_1_5
  - Rectangular_Patch_Array_1_6
  - Rectangular_Patch_Array_1_7
  - Rectangular_Patch_Array_1_8
  - Rectangular_Patch_Array_2_1
  - Rectangular_Patch_Array_2_2
  - Rectangular_Patch_Array_2_3
  - Rectangular_Patch_Array_2_4
  - Rectangular_Patch_Array_2_5

array : 1*

Python console

```
>>> App.ActiveDocument=App.getDocument("array")
>>> Gui.ActiveDocument=Gui.getDocument("array")
>>> App.closeDocument("Unnamed")
>>>
```

Preselected: MURBox - array.MURBox. (68.1386, 46.3011, 20.6)   Gestur   126.41 mm x 105.44 mm



Position
Xmin: 0.0000000
Ymin: 0.0000000
Zmin: 0.0000000

Substrate
Length: 1
Width: 2
Height: 0.5
Medium: metal
☑ Ground
Height: 0.1
Medium: metal
☑ Thin Layer
☑ Auto Dimensions

☑ Rectangular Patch
Length: 1
Width: 2
Height: 0.1
Medium: metal
☑ Thin Layer

☐ Circular Patch
Diameter 1: 1
☐ Diameter 2: 2
Height: 0.1
Medium: metal
☑ Thin Layer

☐ Patch Geometry
Set...
Medium: metal

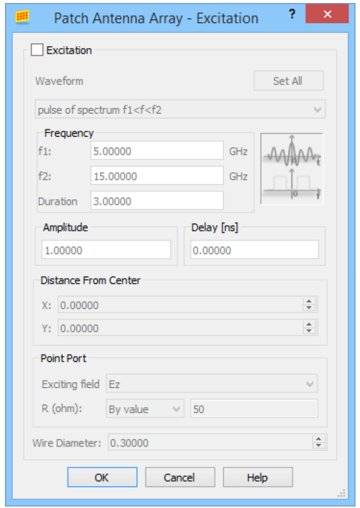
X
Number of Columns: 4
Spacing: 1.5
Margin: 1.5

Y
Number of Rows: 3
Spacing: 1.5
Margin: 1.5

Excitation NOT set

Beam Steering NOT set

NTF/ABC NOT set



☐ Excitation

Waveform: pulse of spectrum f1<f<f2

Frequency
f1: 5.00000 GHz
f2: 15.00000 GHz
Duration 3.00000

Amplitude: 1.00000
Delay [ns]: 0.00000

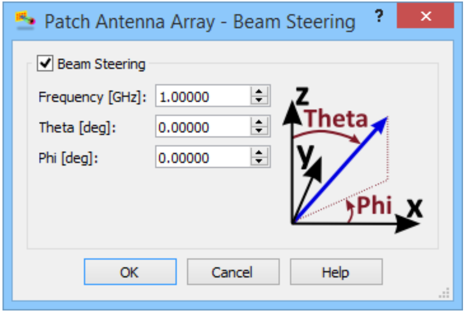
Distance From Center
X: 0.00000
Y: 0.00000

Point Port
Exciting field: Ez
R (ohm): By value 50

Wire Diameter: 0.30000

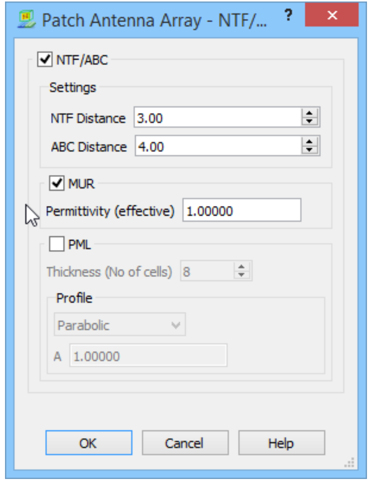
Feed parameters @ each patch

Automatic phase-shift adjustment between patches



☑ Beam Steering
Frequency [GHz]: 1.00000
Theta [deg]: 0.00000
Phi [deg]: 0.00000

User defined main beam angle



☑ NTF/ABC

Settings
NTF Distance 3.00
ABC Distance 4.00

☑ MUR
Permittivity (effective) 1.00000

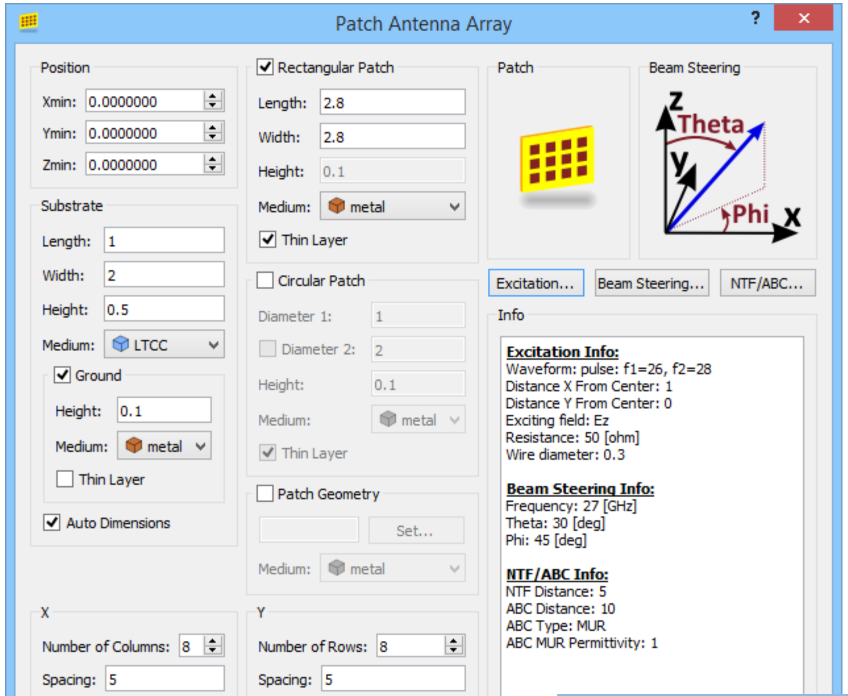
☐ PML
Thickness (No of cells) 8

Profile: Parabolic
A 1.00000

Choice of suitable absorbing BC

- ✓ Various patch shapes, incl. user-defined geometries
- ✓ Automatic substrate/ground inclusion, incl. dimensions auto-scaling
- ✓ Automatic matrix arrangement

Dedicated simulation & display regimes for 5G patch antenna analysis



Position
Xmin: 0.0000000
Ymin: 0.0000000
Zmin: 0.0000000

Substrate
Length: 1
Width: 2
Height: 0.5
Medium: LTCC
☑ Ground
Height: 0.1
Medium: metal
☐ Thin Layer
☑ Auto Dimensions

☑ Rectangular Patch
Length: 2.8
Width: 2.8
Height: 0.1
Medium: metal
☑ Thin Layer

☐ Circular Patch
Diameter 1: 1
☐ Diameter 2: 2
Height: 0.1
Medium: metal
☑ Thin Layer

☐ Patch Geometry
Set...
Medium: metal

X
Number of Columns: 8
Spacing: 5
Margin: 2

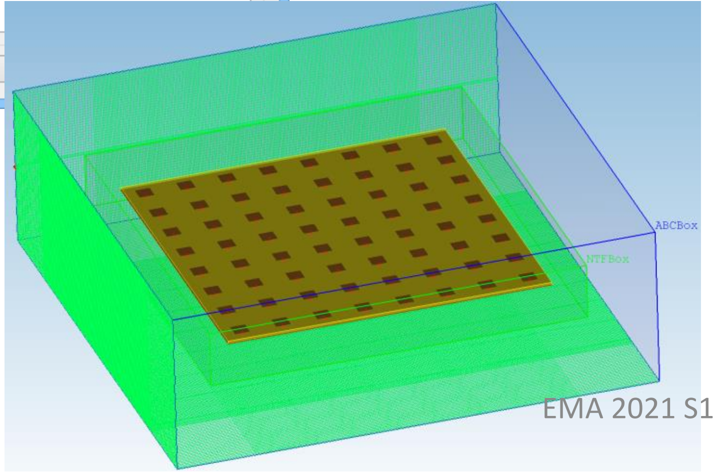
Y
Number of Rows: 8
Spacing: 5
Margin: 2

Info

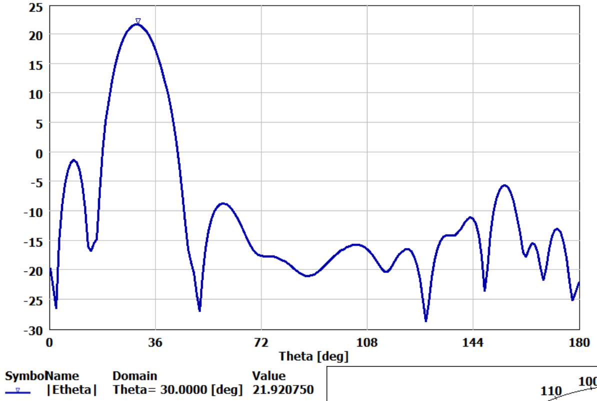
Excitation Info:
Waveform: pulse: f1=26, f2=28
Distance X From Center: 1
Distance Y From Center: 0
Exciting field: Ez
Resistance: 50 [ohm]
Wire diameter: 0.3

Beam Steering Info:
Frequency: 27 [GHz]
Theta: 30 [deg]
Phi: 45 [deg]

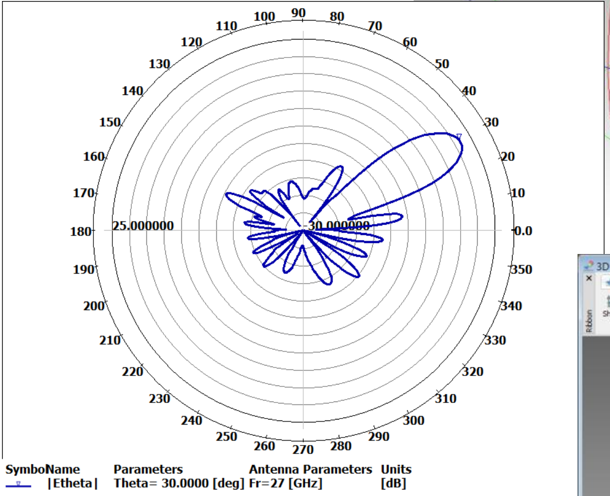
NTF/ABC Info:
NTF Distance: 5
ABC Distance: 10
ABC Type: MUR
ABC MUR Permittivity: 1

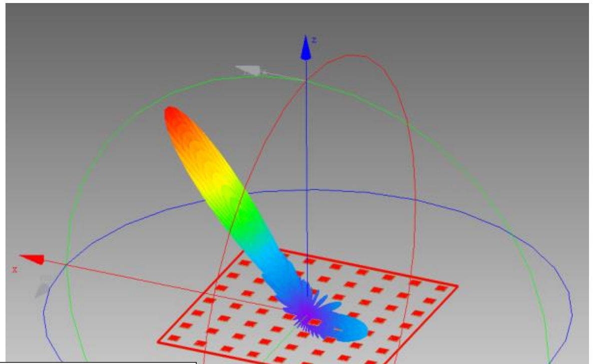


LTCC-based 8x8 patch array



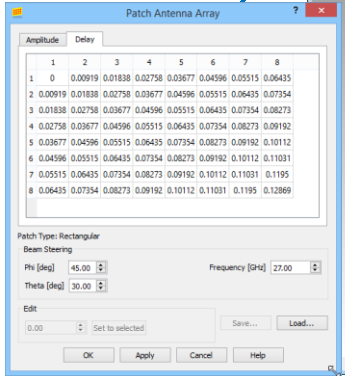
2D radiation patterns





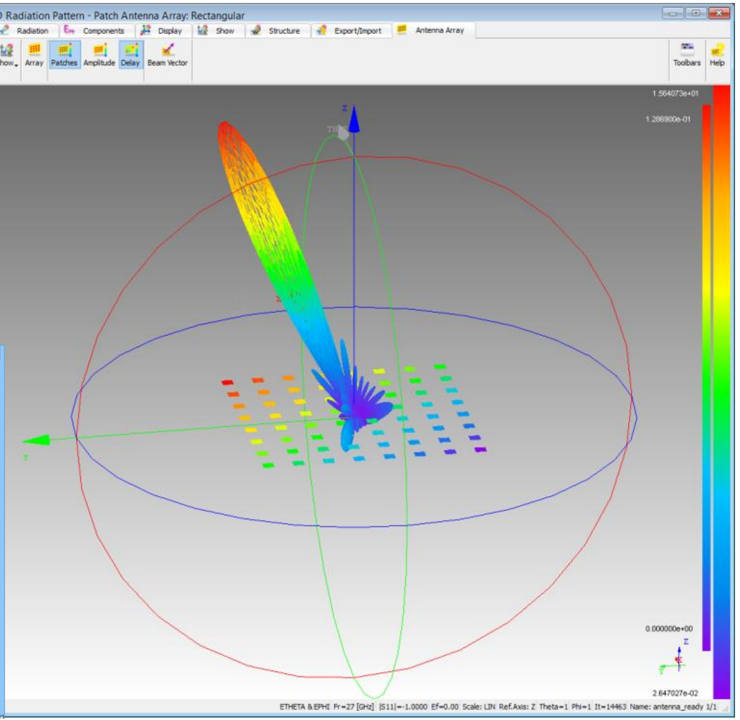
3D radiation pattern

Distribution of source phase shifts across the array



	1	2	3	4	5	6	7	8
1	0	0.00919	0.01838	0.02758	0.03677	0.04596	0.05515	0.06435
2	0.00919	0.01838	0.02758	0.03677	0.04596	0.05515	0.06435	0.07354
3	0.01838	0.02758	0.03677	0.04596	0.05515	0.06435	0.07354	0.08273
4	0.02758	0.03677	0.04596	0.05515	0.06435	0.07354	0.08273	0.09192
5	0.03677	0.04596	0.05515	0.06435	0.07354	0.08273	0.09192	0.10112
6	0.04596	0.05515	0.06435	0.07354	0.08273	0.09192	0.10112	0.11031
7	0.05515	0.06435	0.07354	0.08273	0.09192	0.10112	0.11031	0.1195
8	0.06435	0.07354	0.08273	0.09192	0.10112	0.11031	0.1195	0.12869

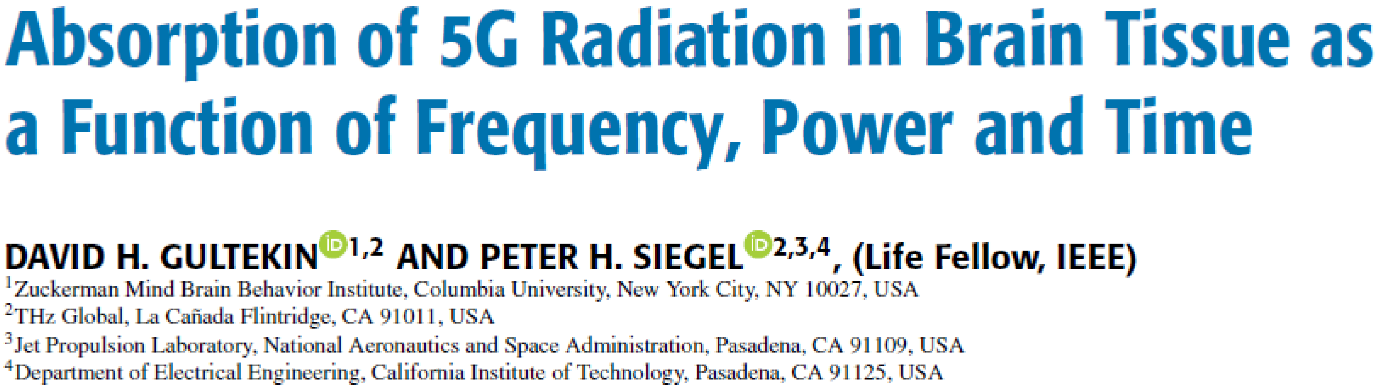
Patch Type: Rectangular
Beam Steering
Phi [deg] 45.00
Frequency [GHz] 27.00
Theta [deg] 30.00
Edit
0.00
Set to selected



ETHETA & EPHI Fr=27 [GHz] |S11|=-1.0000 Ef=0.00 Scale: LIN Ref.Axis: Z Theta=1 Phi=1 It=14463 Name: antenna_ready 1/1

Modelling EM field interaction with tissues

Recent research
on 5G safety
June 2020



Absorption of 5G Radiation in Brain Tissue as a Function of Frequency, Power and Time

DAVID H. GULTEKIN[1,2] **AND PETER H. SIEGEL**[2,3,4]**, (Life Fellow, IEEE)**
[1]Zuckerman Mind Brain Behavior Institute, Columbia University, New York City, NY 10027, USA
[2]THz Global, La Cañada Flintridge, CA 91011, USA
[3]Jet Propulsion Laboratory, National Aeronautics and Space Administration, Pasadena, CA 91109, USA
[4]Department of Electrical Engineering, California Institute of Technology, Pasadena, CA 91125, USA

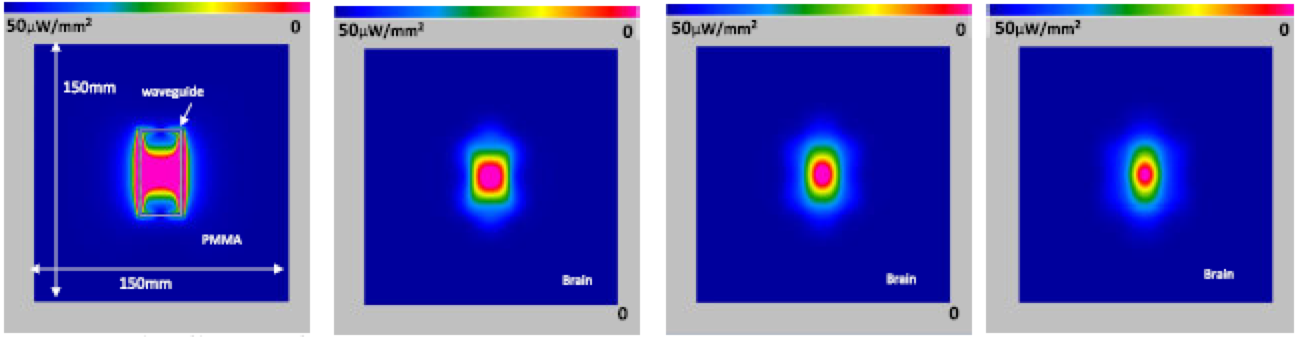
IEEE Access
Multidisciplinary ⁝ Rapid Review ⁝ Open Access Journal

QuickWave modelling applied
to interpret laboratory experiments
with bovine tissue irradiation

4 GHz

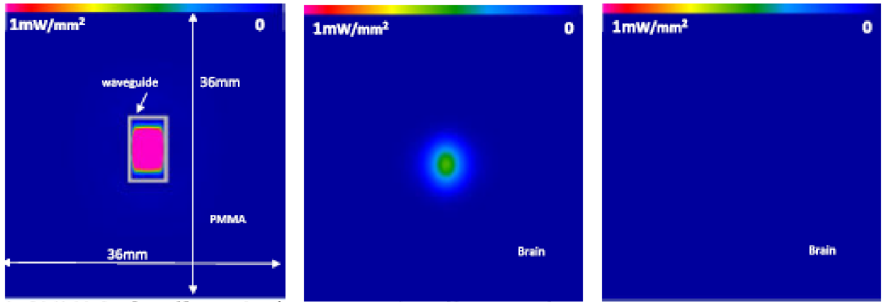
39 GHz

Simulated Surface Power Density (µW/mm²) at **4 GHz** vs. Depth in Brain Tissue. LINEAR SCALE: Pink=50µW/mm²; Blue=0



At PMMA Surface (front view) | 1mm deep (front view) | 6mm deep (front view) | 11mm deep (front view)

Simulated Surface Power Density (µW/mm²) at **39 GHz** vs. Depth in Brain Tissue. LINEAR SCALE: Pink=1mW/mm²; Blue=0

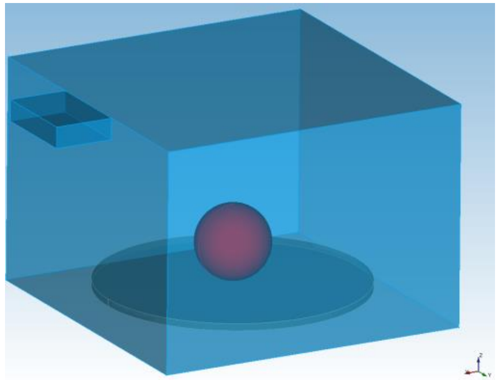


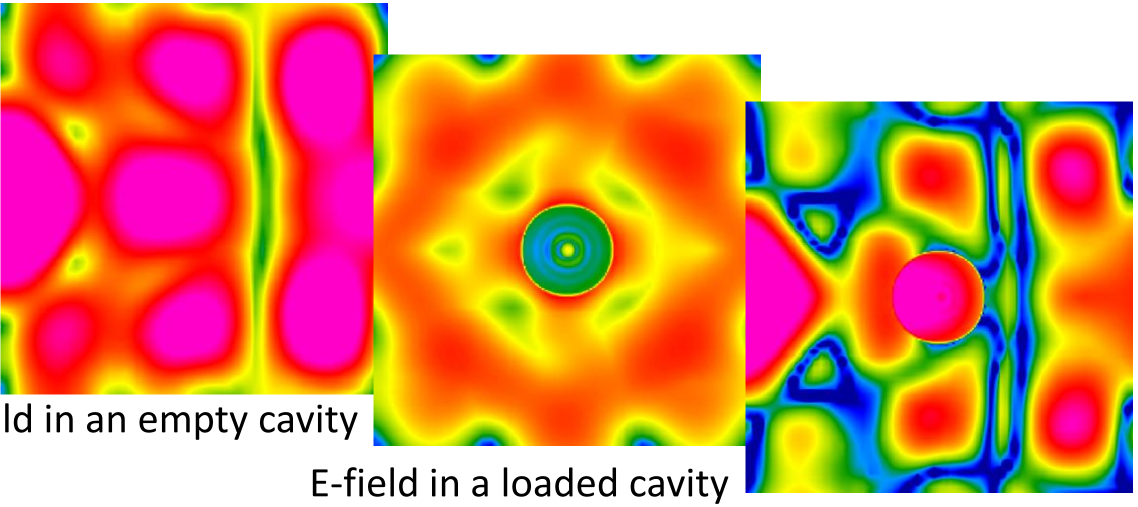
At PMMA Surface (front view) | 1mm deep (front view) | 6mm deep (front view)

Using 1W of incident power,
an average power density of 138, 613 and 16 578 W/m2 (at 1.9, 4, 39GHz, respectively)
is derived at the tissue surface.

Modelling EM field interaction with tissues

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

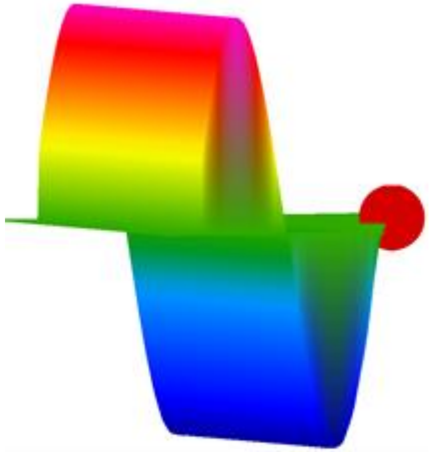


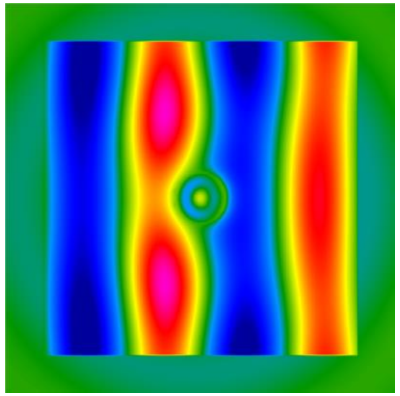


E-field in an empty cavity

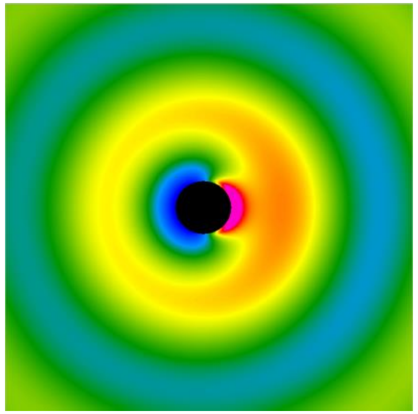
E-field in a loaded cavity

Scattered near-filed in cavity



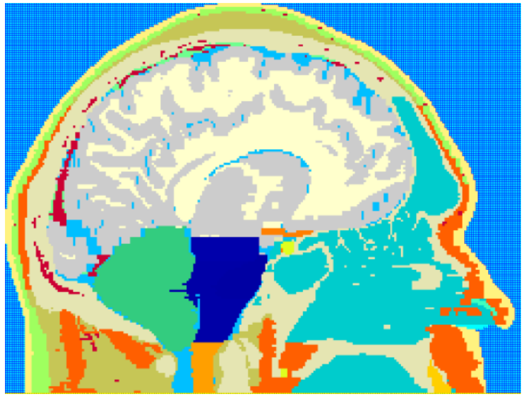


Total field
Focusing by the load
„exploding egg effect”

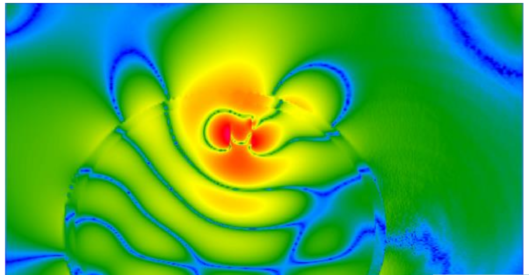


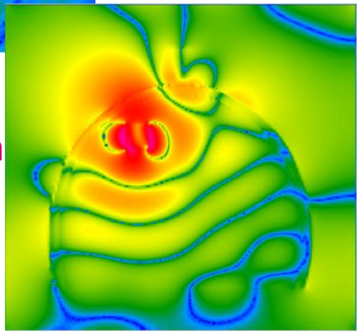
Diffracted field reveals cause of focusing: circumferential resonance

Detection of inhomogenities in tissues



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





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

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

Acknowledgements

The work presented has received funding from the

European Union’s Horizon 2020

research and innovation programme

under grant agreement

NanoBat No 861962.

(website: www.nanobat.eu)

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Simulations conducted with QuickWave EM software, developed & commercialised by QWED.

The original designs of QWED resonators for material measurements from Prof. Jerzy Krupka, e.g.:

J. Krupka, A. P. Gregory, O. C. Rochard, R. N. Clarke, B. Riddle, and J. Baker-Jarvis, “Uncertainty of complex permittivity measurements by split-post dielectric resonator technique”, *J. Eur. Ceramic Soc.*, vol. 21, pp. 2673-2676, 2001.

J. Krupka and J. Mazierska, “Contactless measurements of resistivity of semiconductor wafers employing single-post and split-post dielectric-resonator techniques,” *IEEE Trans. Instr. Meas.*, vol. 56, no. 5, pp. 1839-1844, Oct. 2007.

Scenarios of microwave medical applicators from Per O. Risman, Microtrans AB & Malardalen University, Sweden.

Conclusions

With this talk we seek collaborations:

on the development of:

- **material measurement test-fixtures,**
- **applicators for processing of materials,**
- **software models & workflows**

for 5G materials & applications.

on behalf of:

- **QWED team,**
- **our European project NanoBat,**
- **members of broader EU initiatives, e.g.**

European Materials Modelling Council.

THANK YOU!

...and hoping to talk to you in person next year...