IC1301 - WiPE

Wireless Power Transmission for Sustainable Electronics

25th March 2014
Edinburgh

Jan Kracek

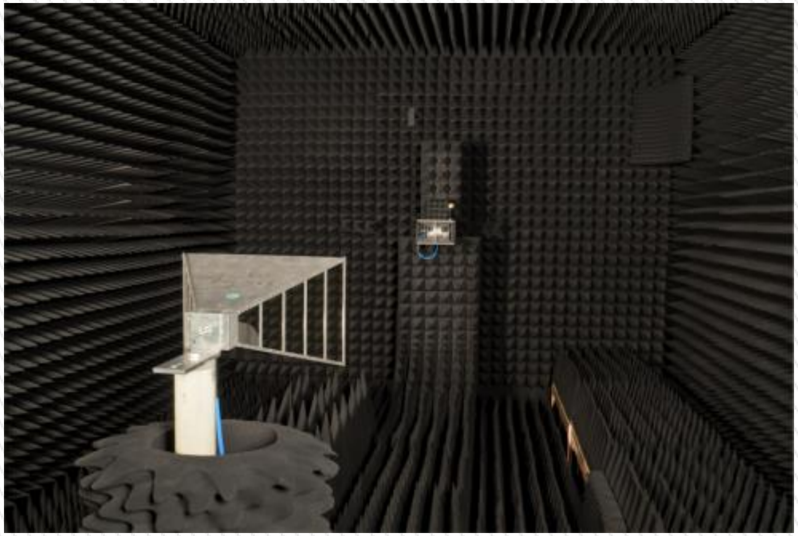
Czech Technical University in Prague

WIPE
COST IC1301

European Science Foundation
cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Department of Electromagnetic Field

- Focus
  - Antennas and propagation
  - Microwaves, mm waves
  - Numerical methods and electromagnetic field modelling
  - Antenna, mw and EMC/EMI, measurement
  - Optoelectronics, FSO
  - Biomedical industriel and applications



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17	academic
13	researchers
2	administrative, technician staff
24	PhD

Czech Technical University in Prague
Department of Electromagnetic Field

» Theory of electromagnetic field
» Computational electromagnetic using analytical and numerical methods
» Electromagnetic compatibility
» Design of induction coils, antennas, microwaves circuits, RFID sensors
» New radiative (coupling) (meta)structures
» SIW

WG1

- Methods of tuning of complex input impedance of antennas for passive RFID transponders and implantable sensors for UHF and microwaves frequency bands
- Methods of space diversity for increasing of identification transponders on human body in spaces with shading of identified persons
- Low profile antennas for passive RFID transponders in UHF frequency band
- Coupling of microwave energy into human body for implantable sensors

WG2

» Analysis of electromagnetic field of induction coils and extraction their circuit parameters

» Analysis of power losses of inductive wireless power transmission

» Homogenization of inductive wireless power transmission for moving appliance

» Optimization of induction coils

WG3

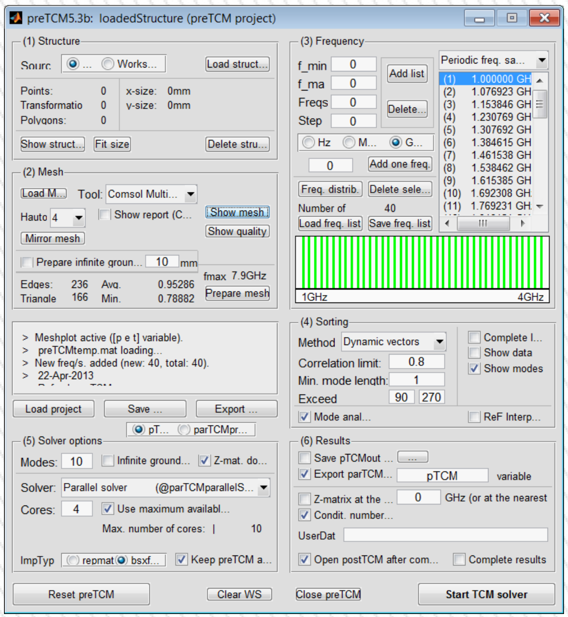
- New radiative (coupling) structures, metastractures
- SIW and human body

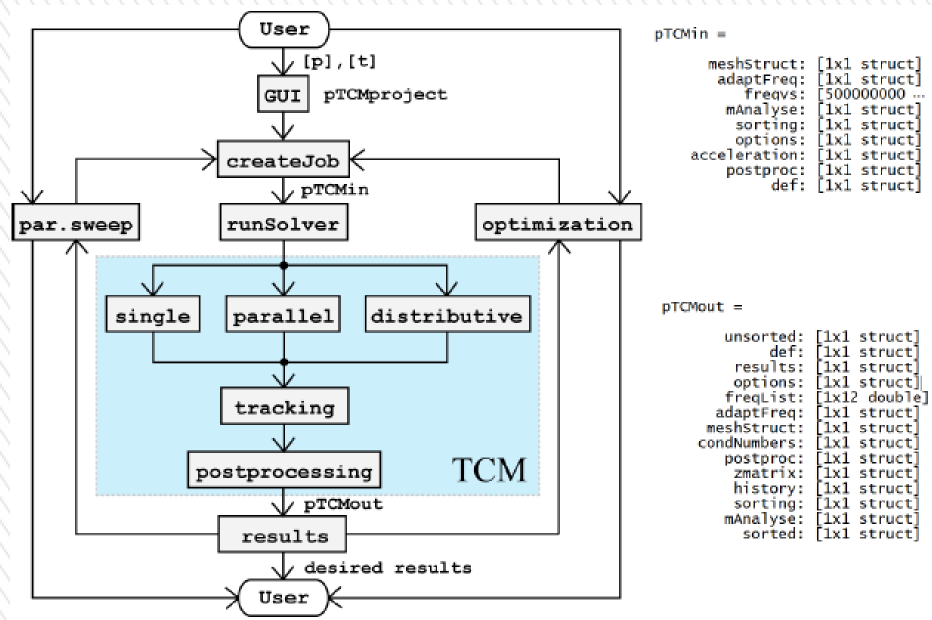
CTU Team

- Jan Kraček, 2 (field coupling)
- Vítězslav Pankrác 2 (field coupling)
- Jan Macháč 3 (SIW, metamaterials)
- Lukáš Jelínek 2,3 (field theory, metastructures)
- Milan Polívka 1 (RFID, wearable antennas)
- Milan Švanda 1 (RFID, wearable antennas)
- Tomáš Kořínek 2,3 (experiments, antennas)
- Miloš Mazánek 2,3 (inductive coupling, antennas)

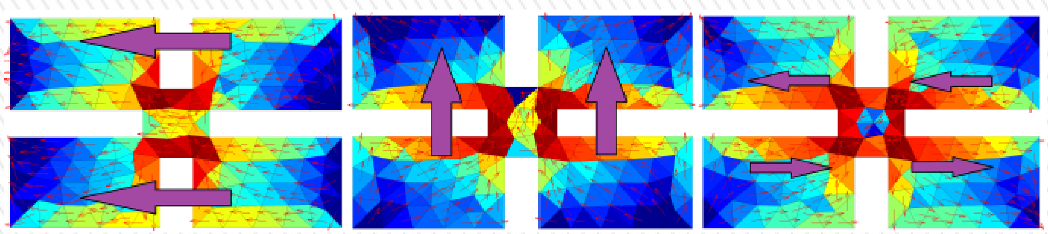
Antenna Theory – MoM/Char. Modes

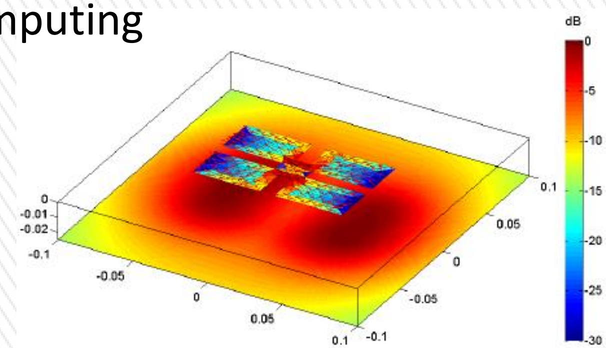
$$\mathcal{F}(J) = \frac{2\omega(W_m - W_e)}{P_r} = \frac{\text{reactive power}}{\text{radiated power}} = \kappa = \frac{\iint_{VV'}\left[k^2 \boldsymbol{J}(\boldsymbol{r})\boldsymbol{J}^*(\boldsymbol{r}') - \nabla\cdot\boldsymbol{J}(\boldsymbol{r})\nabla\cdot\boldsymbol{J}^*(\boldsymbol{r}')\right]\frac{\cos kR}{R}\,d\boldsymbol{r}\,d\boldsymbol{r}'}{\iint_{VV'}\left[k^2 \boldsymbol{J}(\boldsymbol{r})\boldsymbol{J}^*(\boldsymbol{r}') - \nabla\cdot\boldsymbol{J}(\boldsymbol{r})\nabla\cdot\boldsymbol{J}^*(\boldsymbol{r}')\right]\frac{\sin kR}{R}\,d\boldsymbol{r}\,d\boldsymbol{r}'},$$



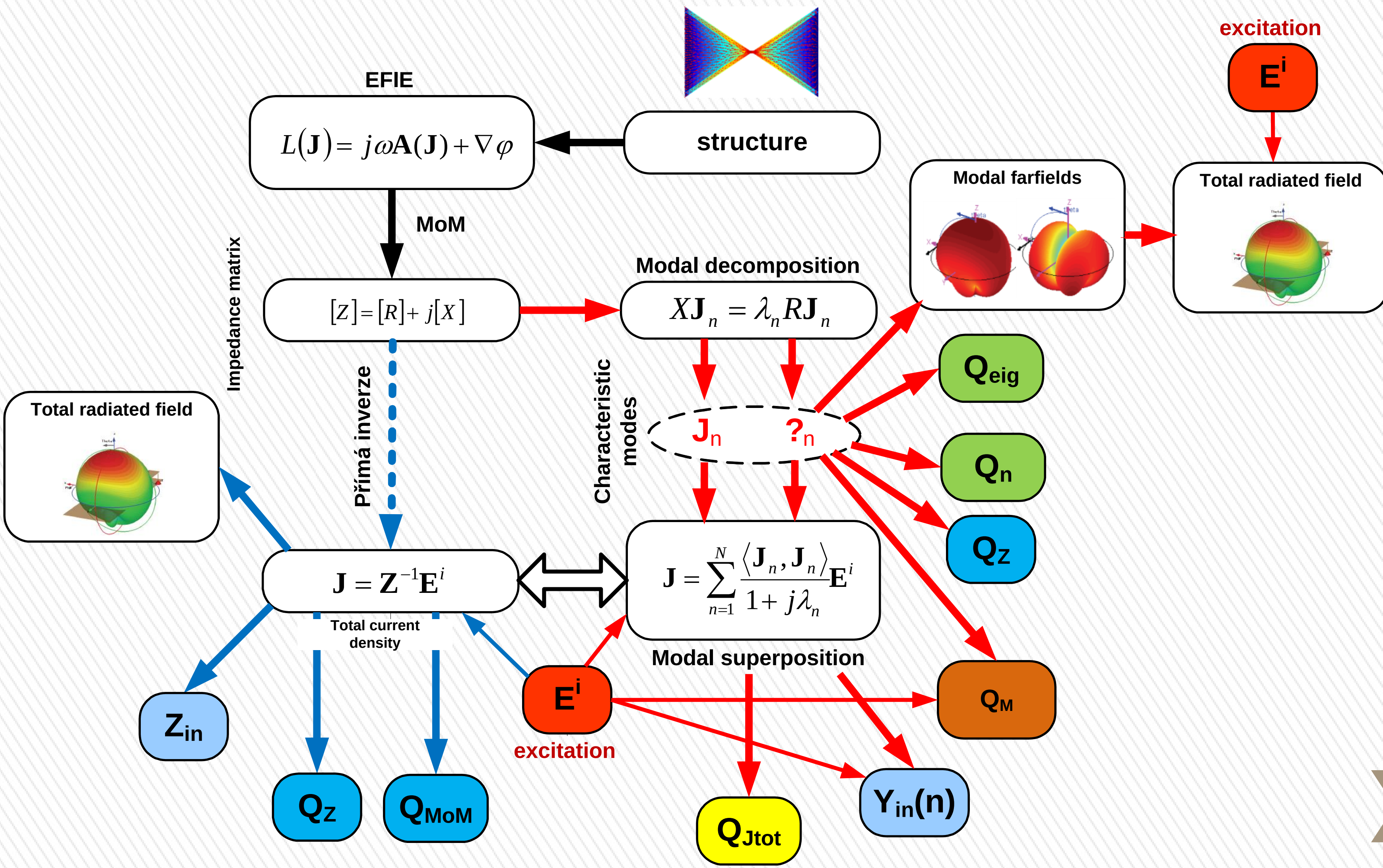


- Parallelization (multiple cores / workstations), GPU computing
- Adaptive frequency sampling



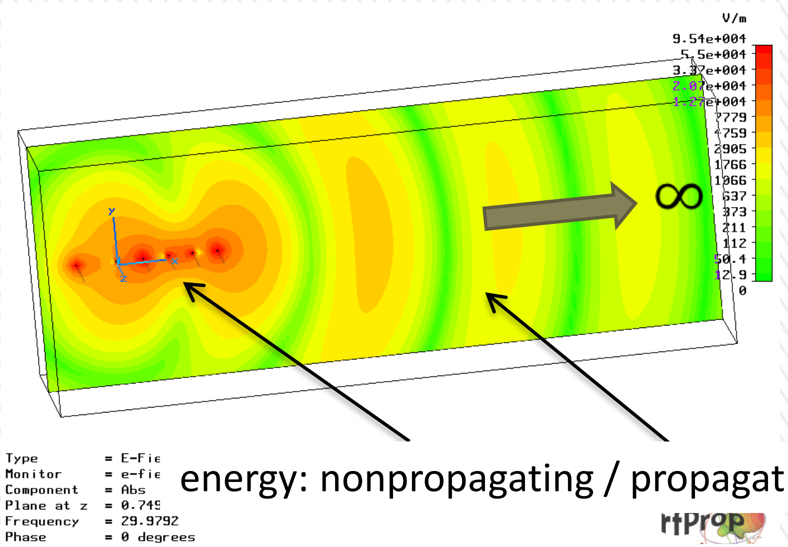


Antenna Theory – MoM/Char. Modes



Antenna Theory – MoM/Char. Modes

» Reactive energies of antennas, Q-factor, superposition of modal quantities

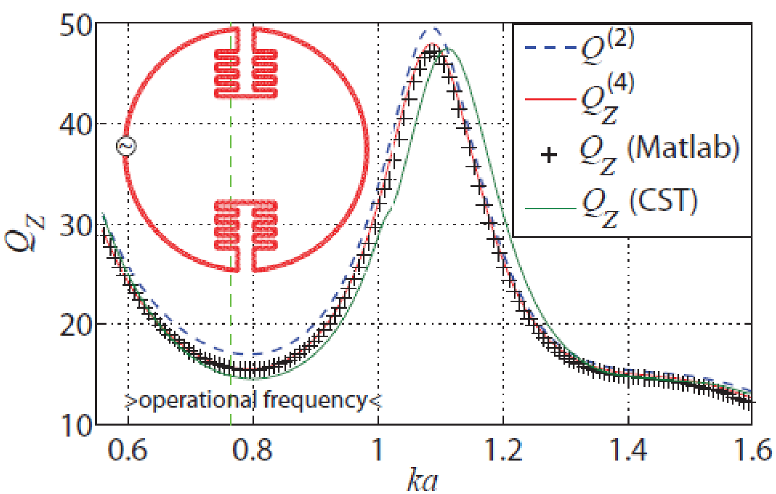


energy: nonpropagating / propagating

$$-\int_V \frac{\boldsymbol{E}\cdot\boldsymbol{J}^*}{2}\,dV = P_r + j2\omega(W_m - W_e)$$

$$-\frac{\omega}{2}\Im\left\{\int_V \boldsymbol{A}\cdot\boldsymbol{J}^* - \phi\rho^*\,dV\right\} \qquad \frac{\omega}{2}\Re\left\{\int_V \boldsymbol{A}\cdot\boldsymbol{J}^* - \phi\rho^*\,dV\right\}$$

Radiated power   Net stored power



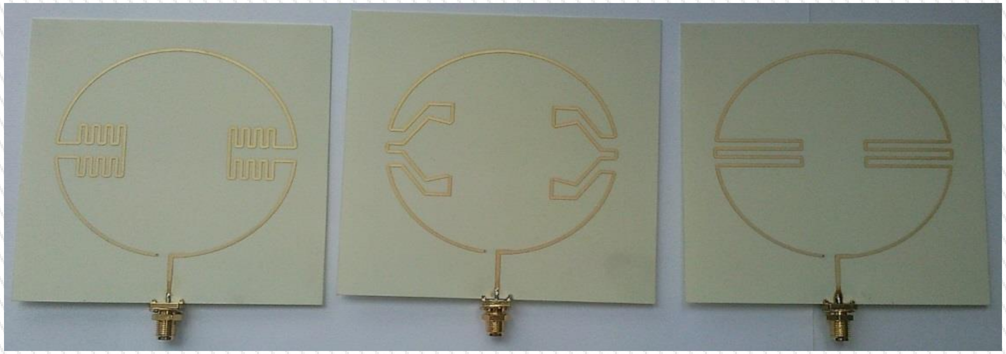
Measurable Q-factor of radiating system

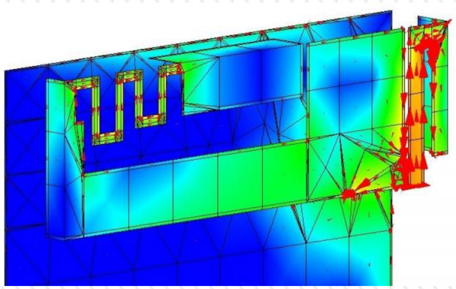
$$Q_Z = \omega_0 \frac{\left|\frac{dZ}{d\omega}\right|}{2R_0}$$

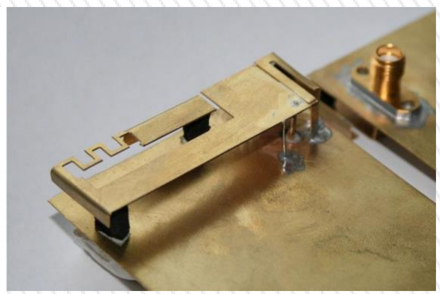
Expressed in terms of energy functional of source current/charge:

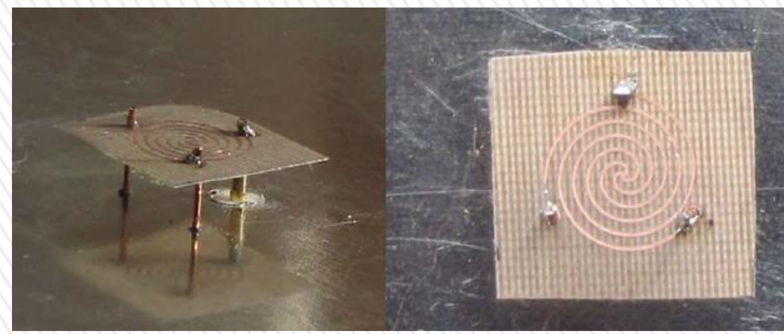
- Electric / magnetic energy
- Dispersion energy related to radiation
- Dispersion energy related to reconfiguration of current

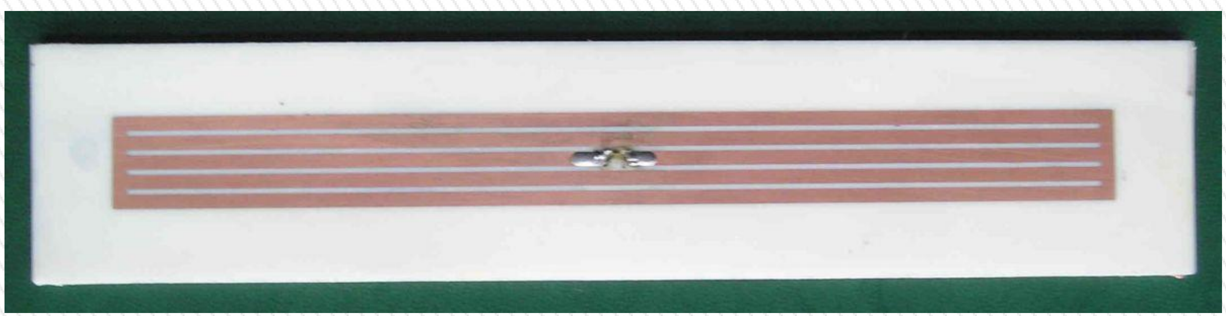
Antenna&Sensor Design – electrically small





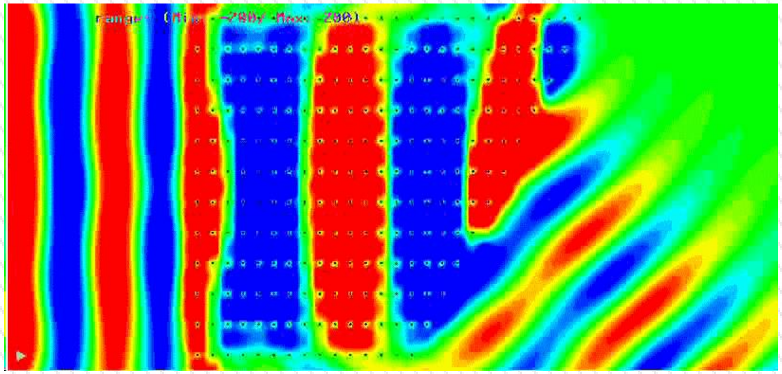


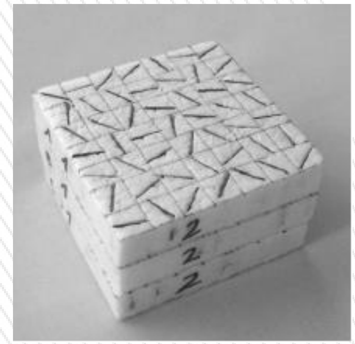


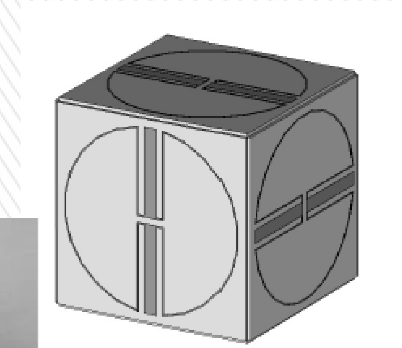


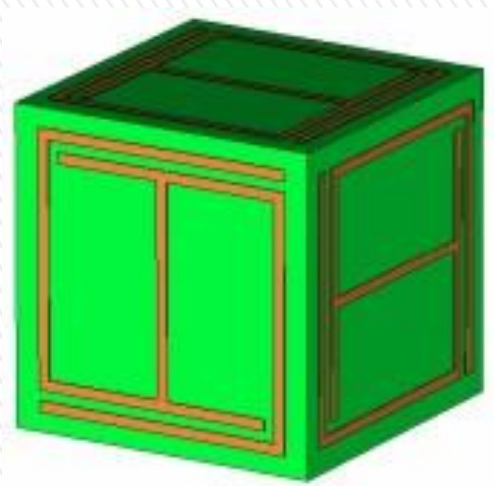
Metamaterials

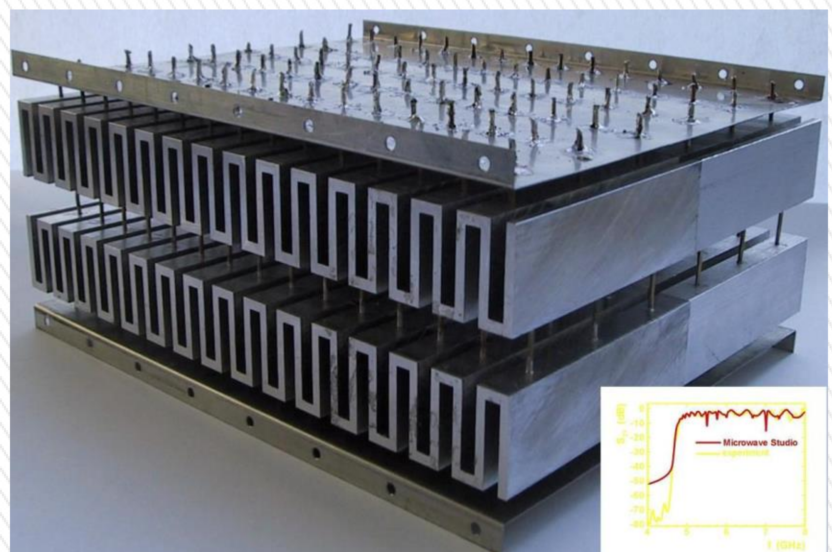
prof. Jan Machac group



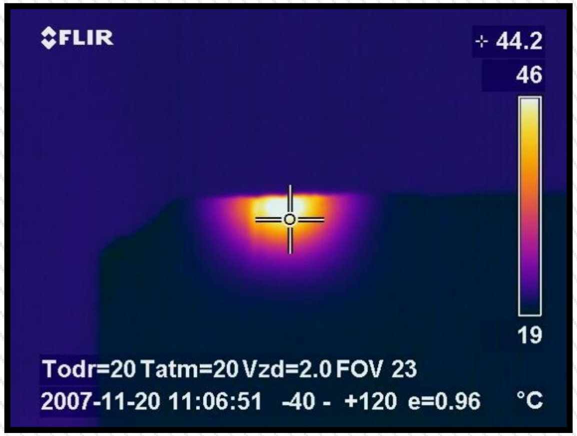


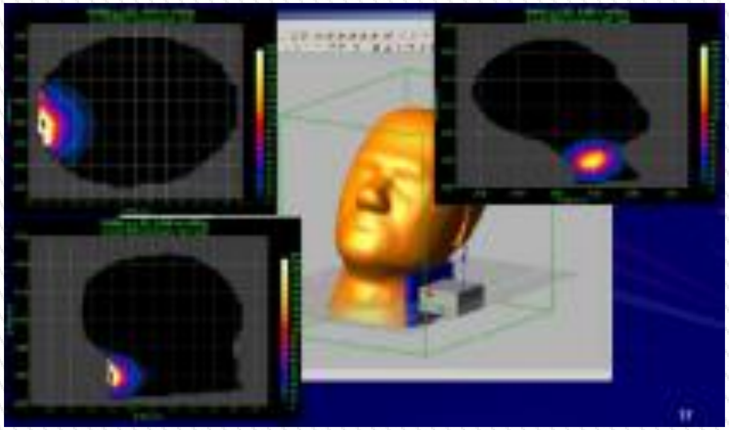


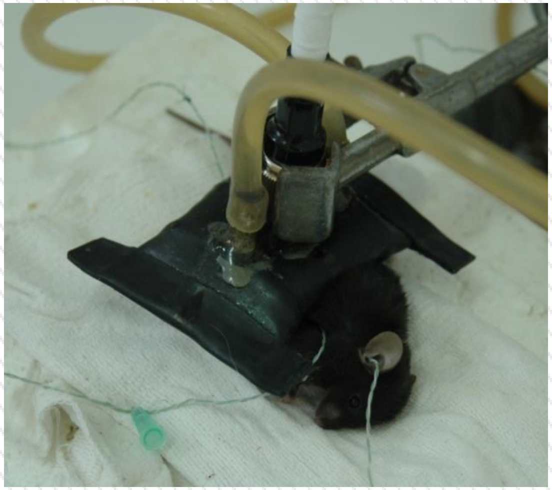




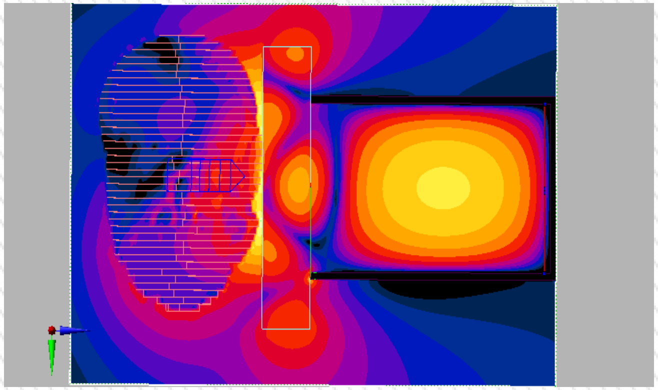
Biological effects of electromagnetic field







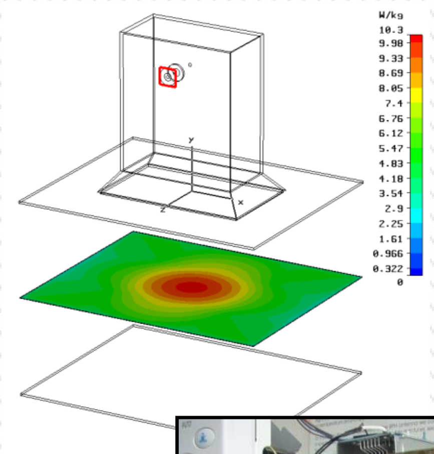
Clinical Testing of Thermotherapy

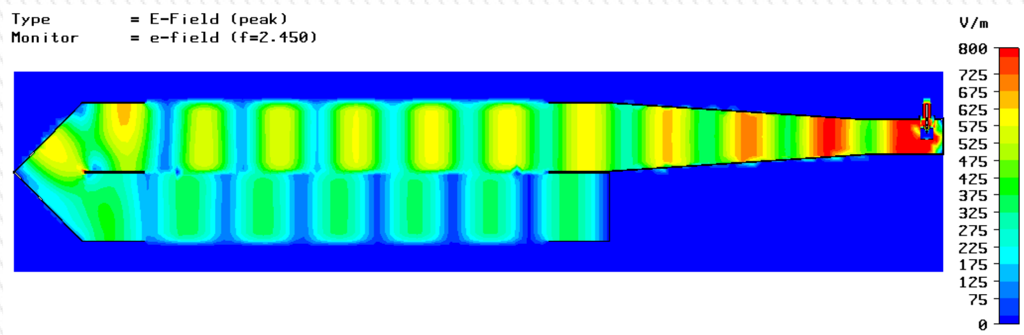


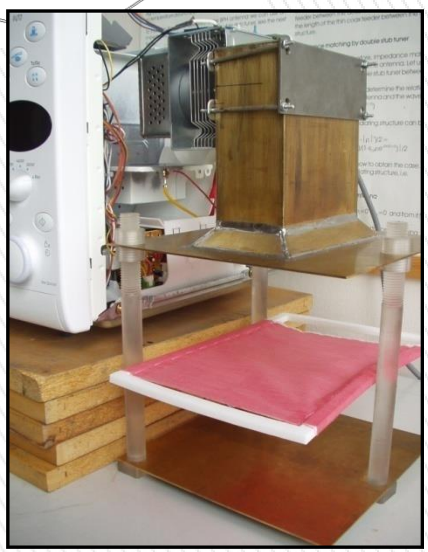
SemCAD

Industrial Applications of Electromagnetic Field

Microwave Drying and Heating







Resonant Type

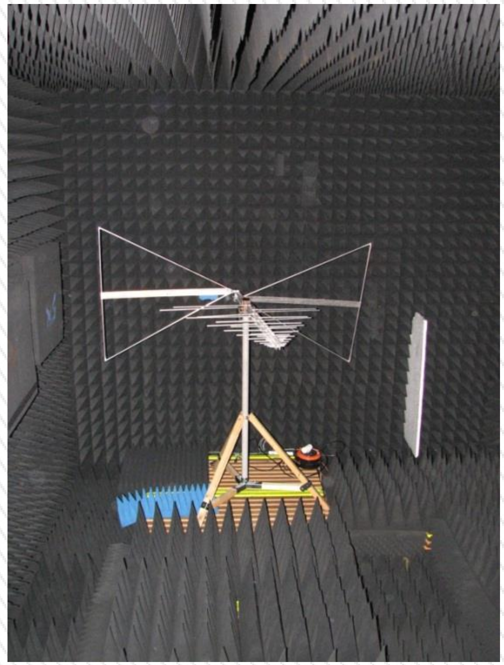
Waveguide Type

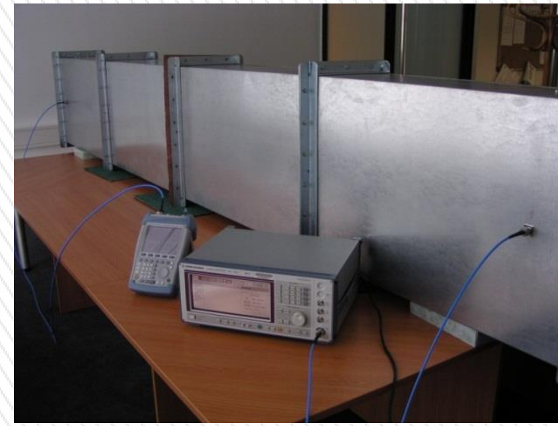
Heating of Acid

EMC/EMI measurement methods

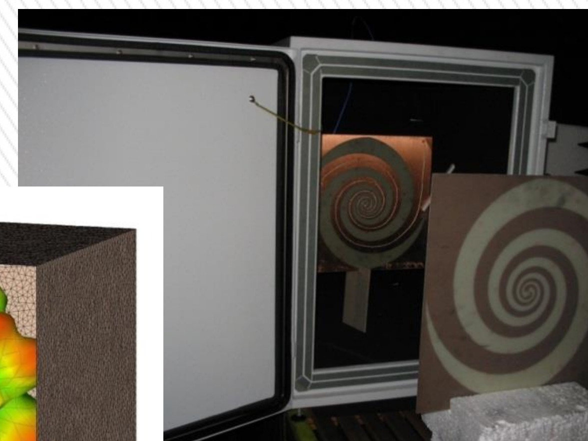
Semi-Anechoic Chamber
80 MHz – 2 GHz

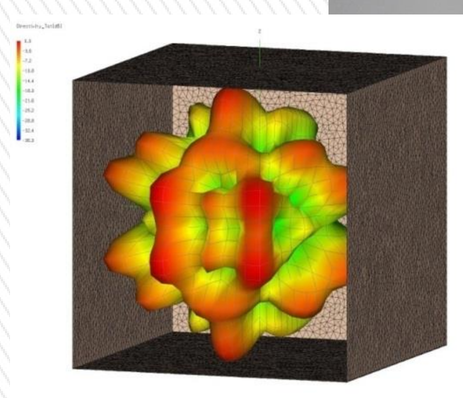
Full Anechoic Chamber
500 MHz – 120 GHz





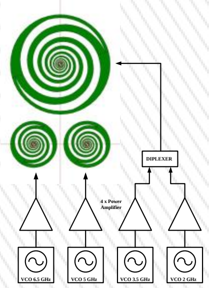
Measurement of Shielding Effectiveness of chambers and thin materials

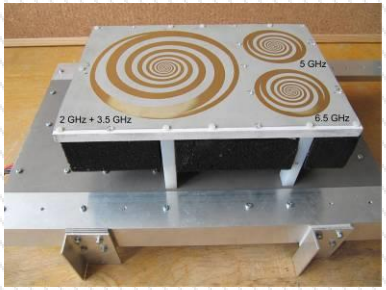


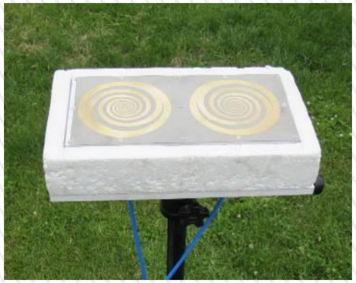


Propagation Measurements for Satellite/HAP/UAV Systems using a Remote-Controlled Airship

- Remote-Controlled Airship
  - 9 m long
  - max. payload of 7 kg
  - CW generators at 2.0, 3.5, 5.0 and 6.5 GHz
  - spiral antennas circular polarization (LHCP)
- Receiver station on the ground – ver. A
  - broadband LHCP spiral antenna
  - portable receiver R&S PR100
  - control sw for measurements at all 4 freq.
- Receiver station on the ground – ver. B
  - 4 narrowband antennas (linear/circular polarization)
  - 4-channel receiver, SISO, 1x4 SIMO/MISO, 2x2 MIMO configurations
  - measurements at 2 GHz only (10 kHz sampling)



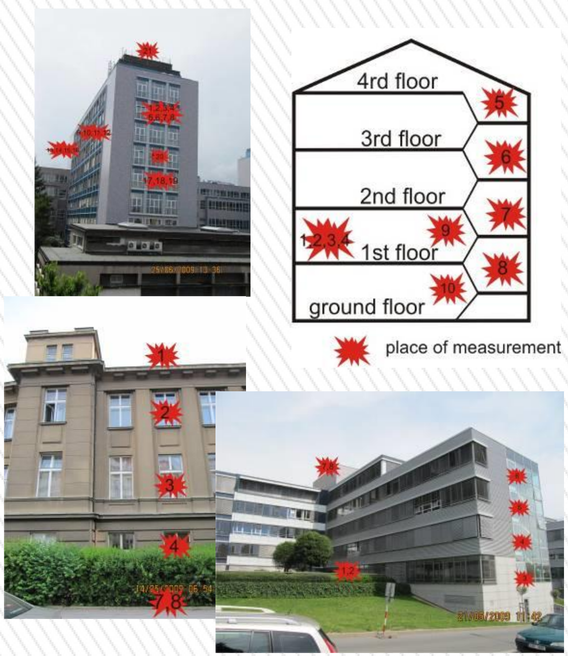


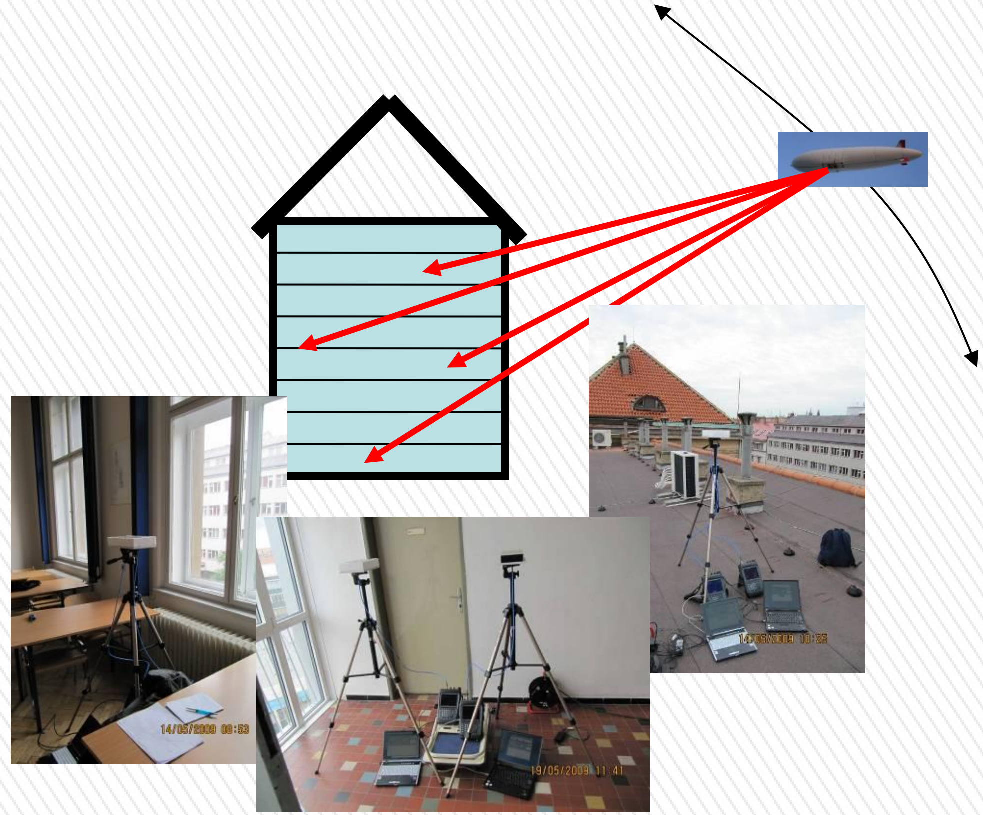


Penetration Loss Measurements

» Measurement trials were conducted at 2.0, 3.5, 5.0 and 6.5 GHz to study signal penetration into buildings as a function of

- elevation angle
- frequency
- receiver position within the building
- building type and surroundings

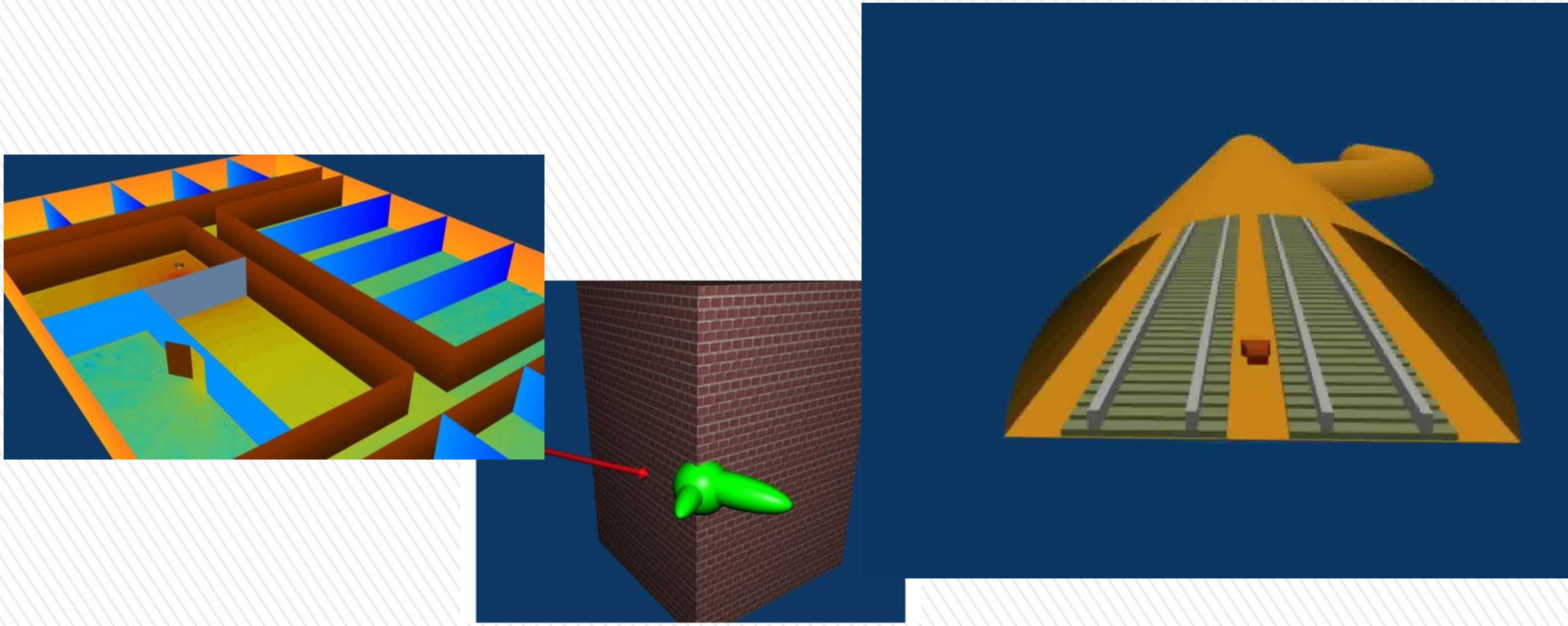




[1] Kvicera, M. - Pechac, P.: Building Penetration Loss for Satellite Services at L-, S- and C-band: Measurement and Modeling, IEEE Transactions on Antennas and Propagation. 2011, vol. 59, no. 8, p. 3013-3021.

[2] Kvicera, M. - Horak, P. - Pechac, P. - Perez-Fontan, F.: On a Definition of Building Penetration Loss for High Elevation Angles, IEEE Transactions on Antennas and Propagation. 2010, vol. 58, no. 12, p. 4115-4118.

New Propagation Modelling Approach

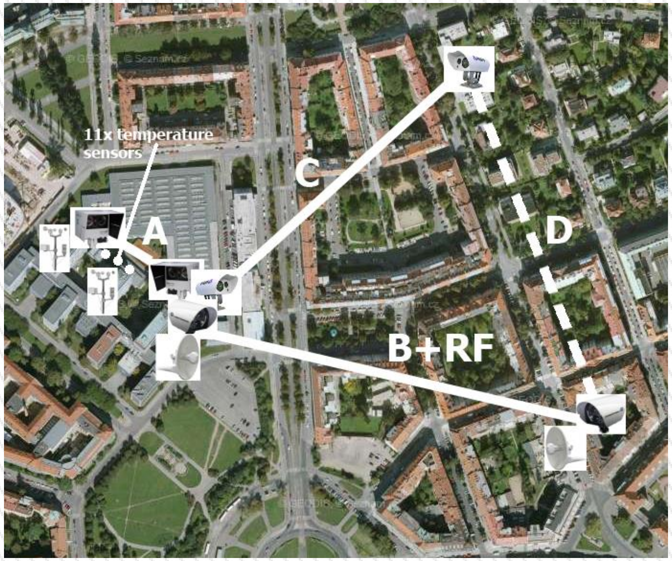


» Basic ray launching, but interactions with obstacles modelled using *3D probability radiation pattern* , Diffuse scattering etc. considered while classical complicated calculations (Fresnel coef., UTD/GTD …) avoided

[1] Subrt, L. - Pechac, P.: Advanced 3D indoor propagation model: calibration and implementation, EURASIP Journal on Wireless Communications and Networking 2011. 2011:180.
[2] Subrt, L. - Pechac, P.: Semi-Deterministic Propagation Model for Subterranean Galleries and Tunnels, IEEE Transactions on Antennas and Propagation. 2010, vol. 58, no. 11, p. 3701-3706.

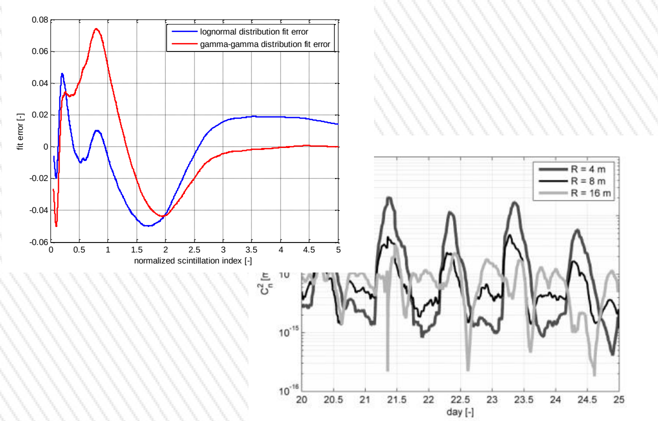
Free-space optics

- Atmospheric influence evaluation
- Diversity techniques
- Ultra-short pulse research
- Beam propagation analyzes
- Indoor optics



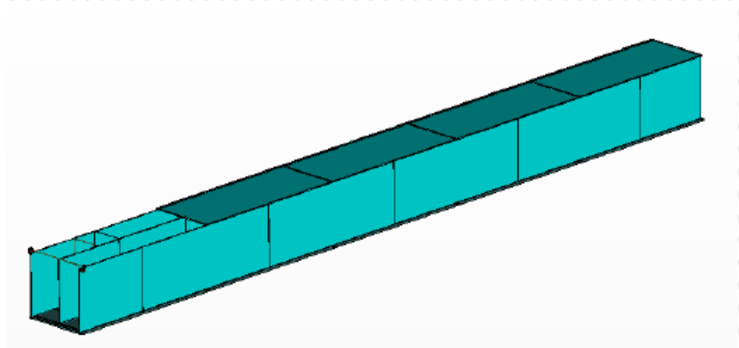
4 FSO links of DEF

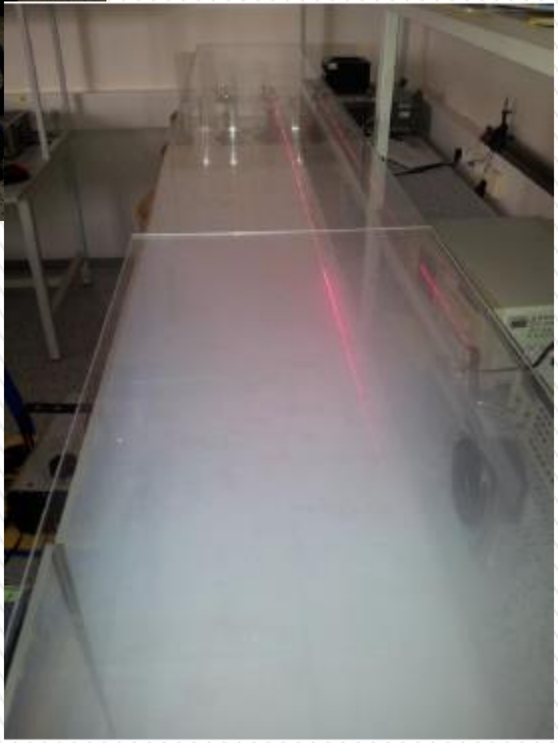
- FlightStrata G by LightPointe,
- 2 x WaveBridge 500 by Plaintree
- MRV TereScope

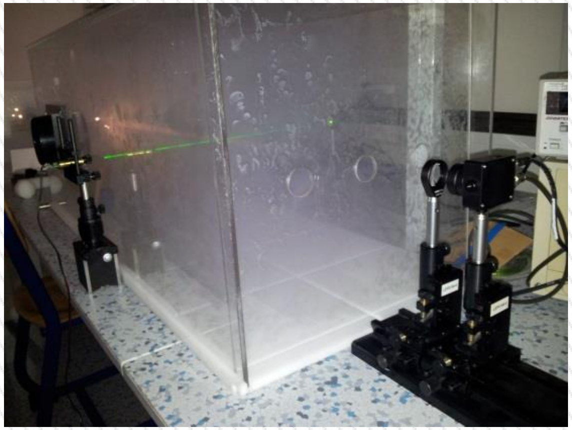


Laboratory

- Modular measurement chamber

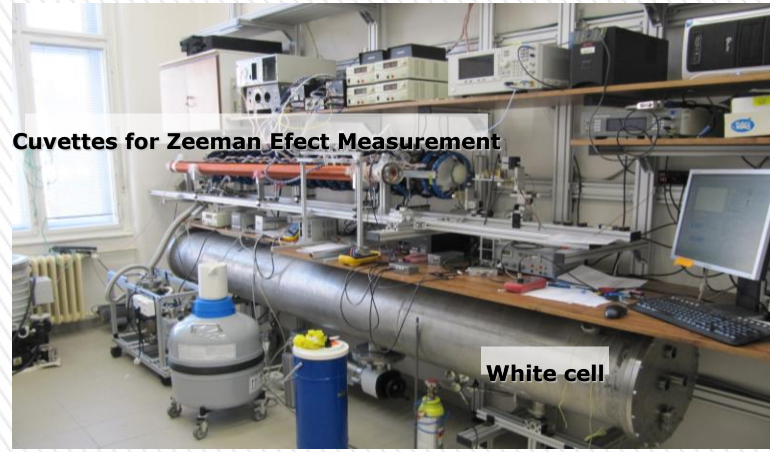


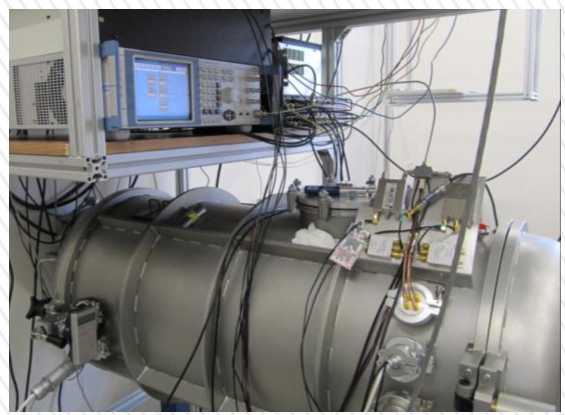


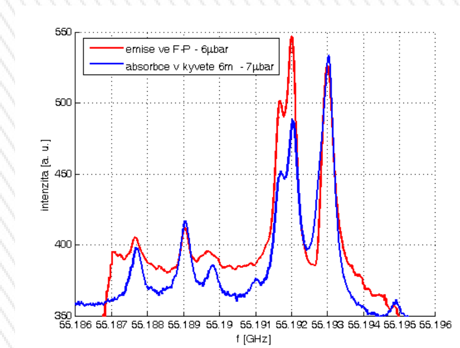


Microwave spectroscopy

» **Fourier Transform Microwave Spectrometer**







[1] Cerný, P. - Piksa, P. - Zvanovec, S. - Korinek, T. - Kabourek, V.: Improved axial feeding of Fabry-Perot resonator for high-resolution spectroscopy applications. Microwave and Optical Technology Letters. 2011, vol. 53, no. 11, p. 2456-2462. ISSN 0895-2477.

[2] Zvanovec, S. - Cerny, P. - Piksa, P. - Korinek, T. – Pechac, P. - et al.: The use of the Fabry-Perot interferometer for high resolution microwave spectroscopy. Journal of Molecular Spectroscopy. 2009, vol. 256, no. 1, p. 141-145. ISSN 0022-2852

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