ATOM
ANTENNA TOOLBOX FOR MATLAB

CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ELECTROMAGNETIC FIELD
TECHNICKÁ 2, 166 27 PRAHA 6, CZECH REPUBLIC

Antenna Toolbox for Matlab (AToM)

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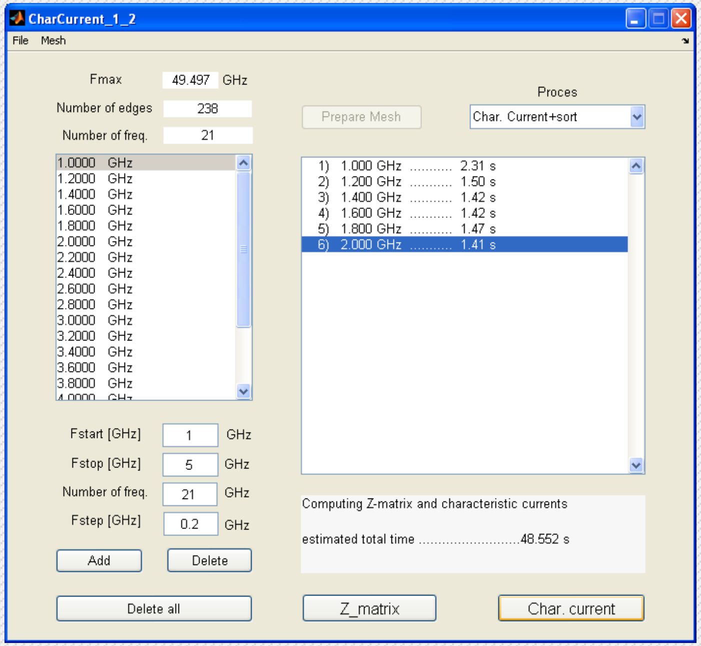
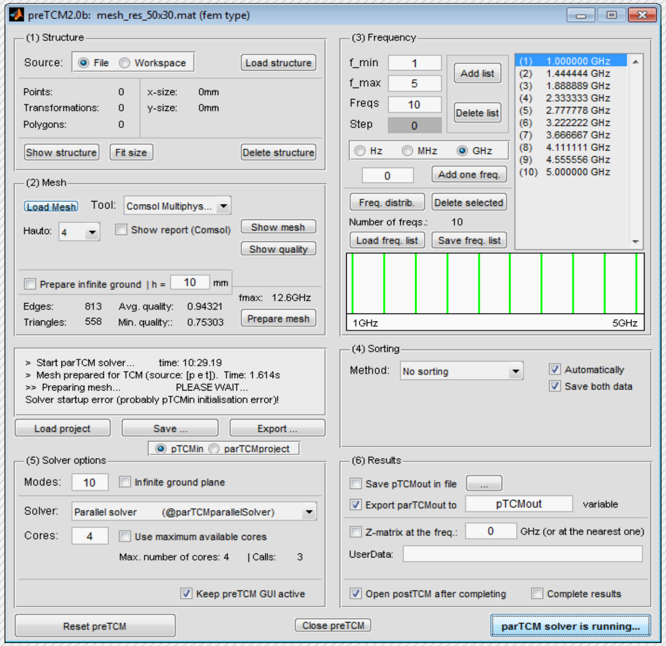
History of the toolbox

- 2008: First software for Method of Moments + Characteristic Modes developed (master thesis of Pavel Hamouz)
- since 2009: Further work within the Ph.D. study of Miloslav Capek and Jan Eichler

2008 version



2014 version



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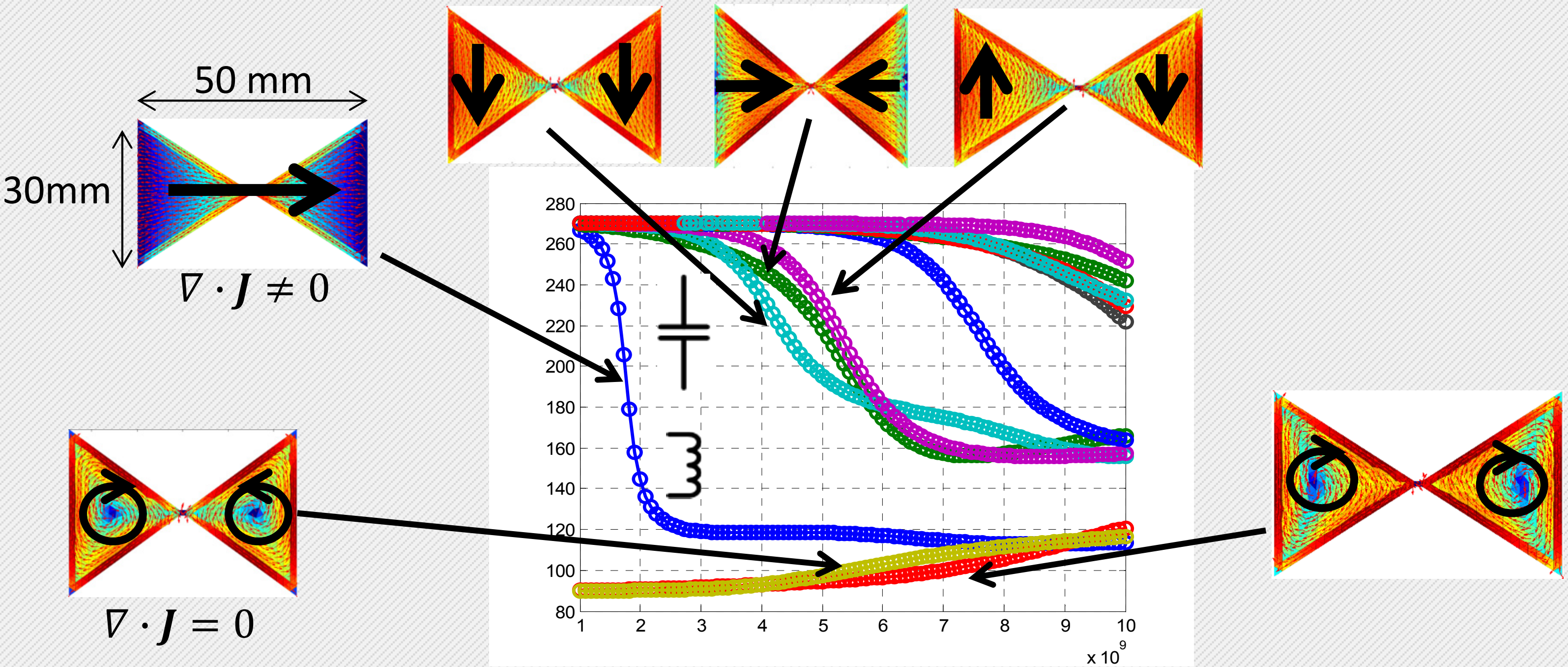
Characteristic Modes

$\boldsymbol{Z} = \boldsymbol{R} + j\boldsymbol{X}$ Complex MoM impedance matrix obtained by Galerkin method

$$F(\boldsymbol{J}) = \frac{\langle \boldsymbol{J}, \boldsymbol{X}\boldsymbol{J} \rangle}{\langle \boldsymbol{J}, \boldsymbol{R}\boldsymbol{J} \rangle} = \frac{\text{reactive power}}{\text{radiated power}} \Rightarrow \boldsymbol{X}\boldsymbol{J}_n = \lambda_n \boldsymbol{R}\boldsymbol{J}_n$$

$\boldsymbol{J}_n$ **characteristic currents**

λ_n **eigenvalues**



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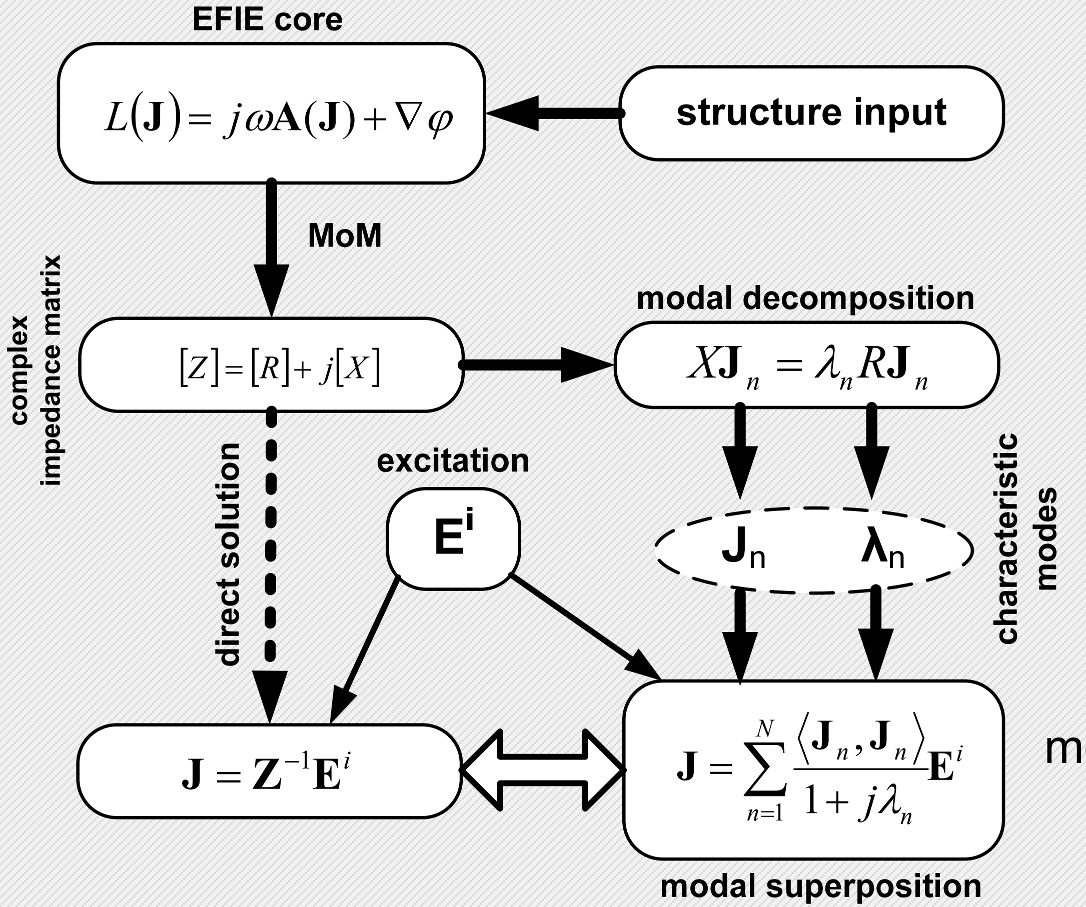
Characteristic Modes



Total current expressed as linear superposition of eigen currents

$$\boldsymbol{J} = \boldsymbol{Z}^{-1}\boldsymbol{E}^i = \sum_{n=1}^{N} \frac{\langle \boldsymbol{J}_n, \boldsymbol{E}^i \rangle}{1 + j\lambda_n} \boldsymbol{J}_n = \sum_{n=1}^{N} \alpha_n \boldsymbol{J}_n$$

For small antennas usually few modes are important → great physical insight into operation of antenna

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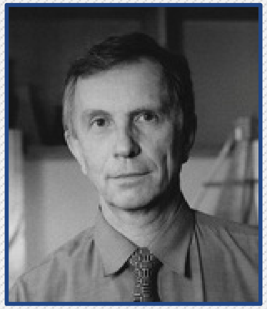
The Antenna toolbox 2014-2017

- funding from the Technology Agency of the Czech Republic received









The Team

CTU FEE in Prague
Brno University of Technology
MECAS ESI Pilsen

+ 5 MSc. / Ph.D. students

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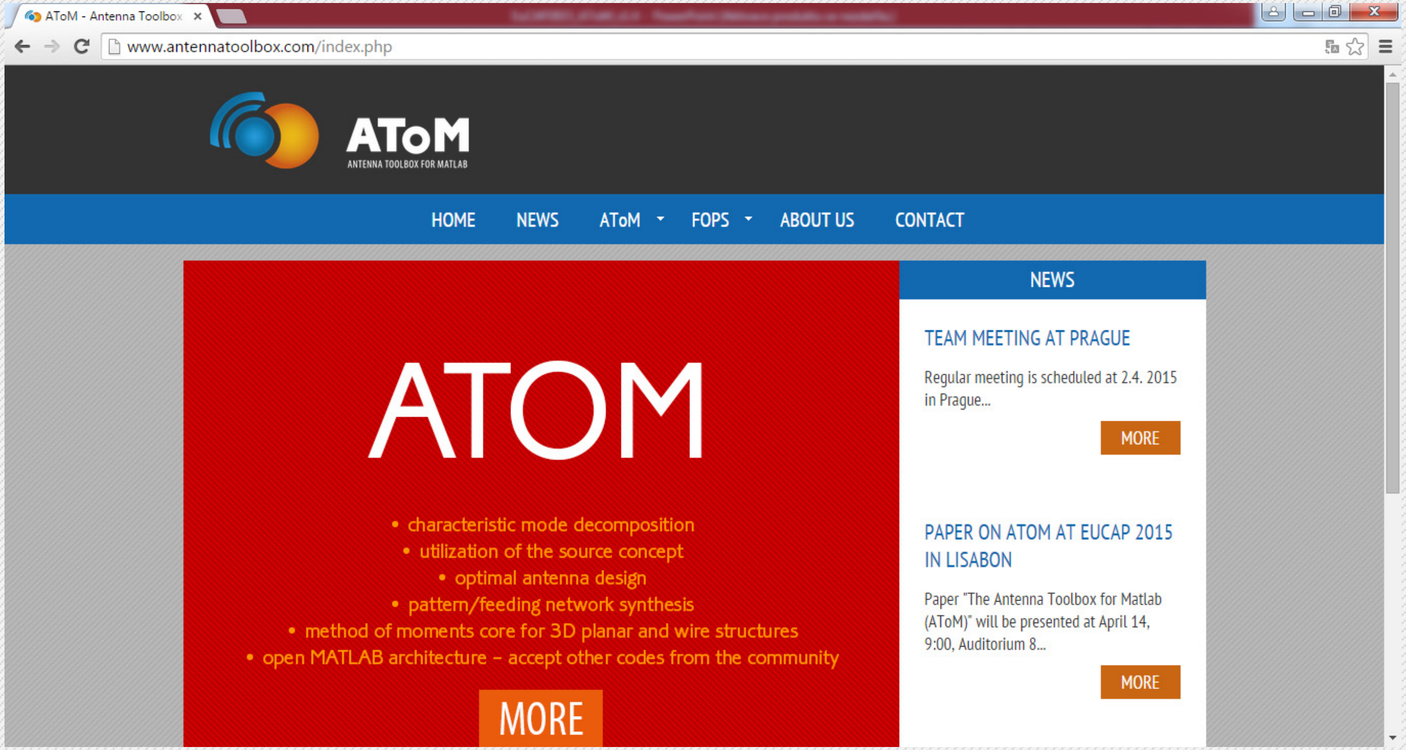
- Project management – IceScrum: distribution of tasks between team members
- Version management – GIT
- Code testing – Matlab unitTest Framework + Jenkins



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Features

- method of moments core for 3D planar and wire structures
- characteristic mode decomposition using Arnoldi and QZ method. Robust tracking.
- Parallel / Distributive solvers, adaptive frequency sweep
- accept other codes from the community - semiopen MATLAB architecture
- pattern / feeding network synthesis
- optimization (FOPS – **F**ast **O**ptimization **P**rocedure**S**), multi-objective PSO, SOMA
- utilization of the ***source concept → antenna can be completely described by its geometry and current (charge) density.***

Structural decomposition

- Input impedance
- Radiation pattern
- Farfield correlation
- Quality factor
- Radiation efficiency

feeding network synthesis

Modal / Total quantities!

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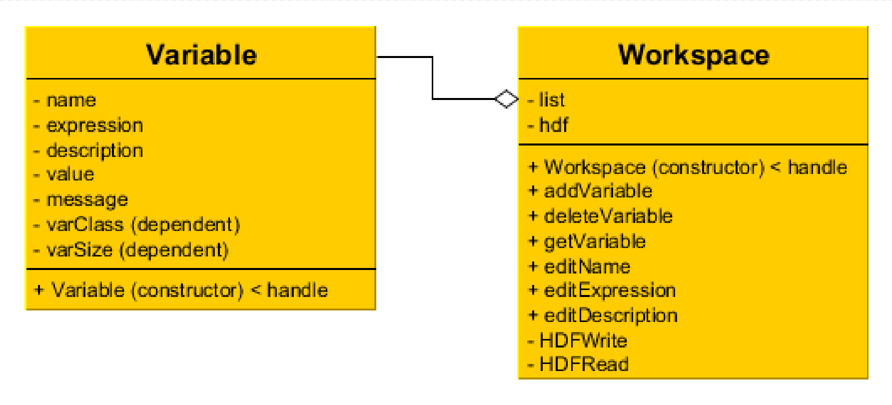
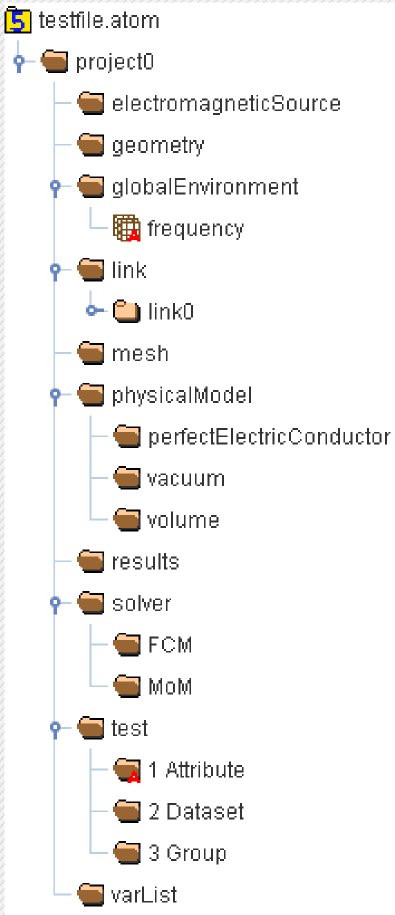
Features



AToM Workspace enables users to define their own parameters and hence make simple parametric design of simulated structure. Drawn geometry interactively reacts on changes in Workspace parameters definitions which makes design more pleasant. During work the Workspace is automatically deposited into HDF file for future reopening of the project.



HDF File format

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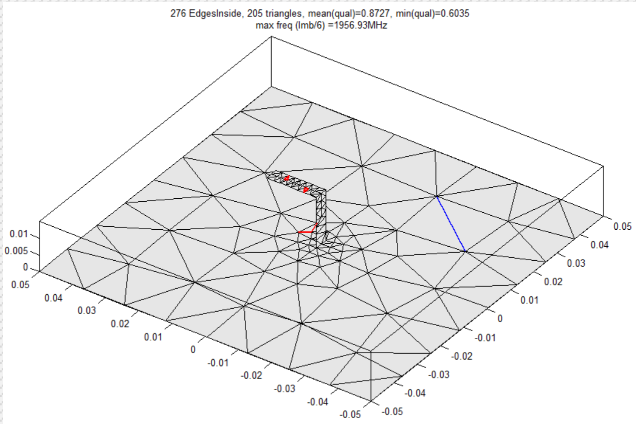
Features

draw_helixAntenna([0 0 0],2,1,10,1)

rotate_y(pi/2)

Geometry + mesh module

- Antenna models
- Geometry transformations
- NEC import



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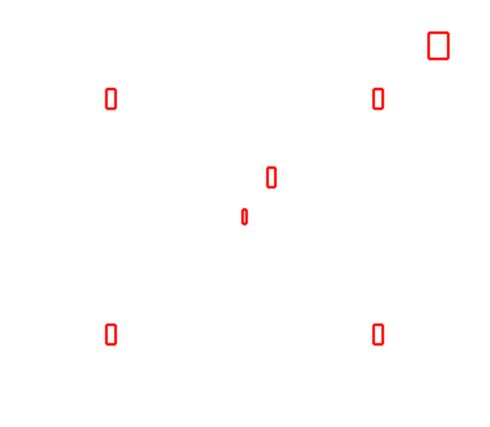

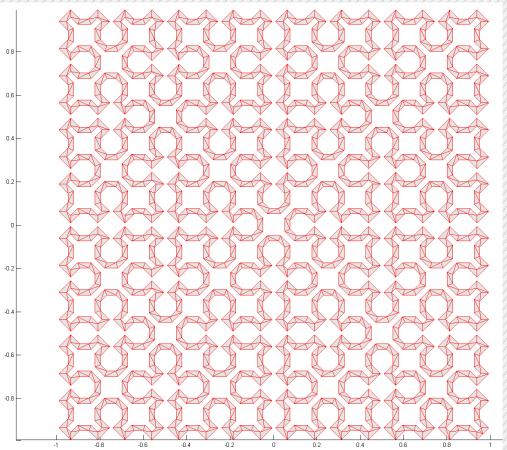

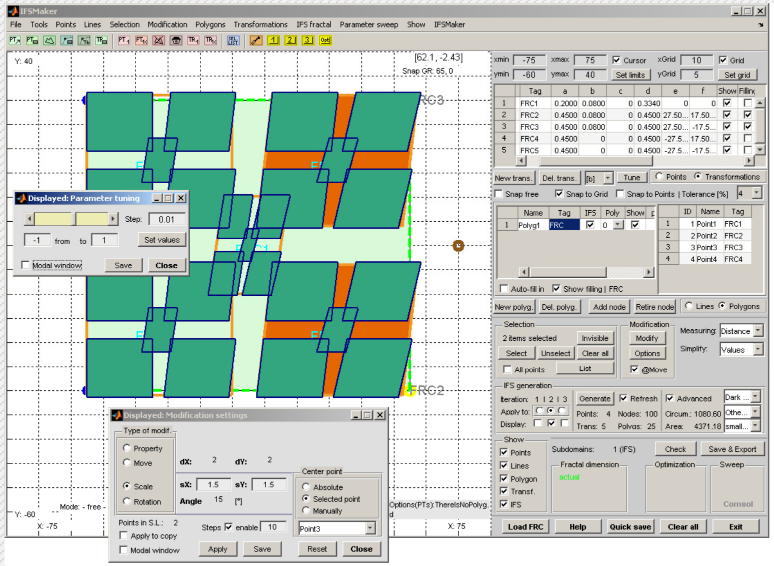

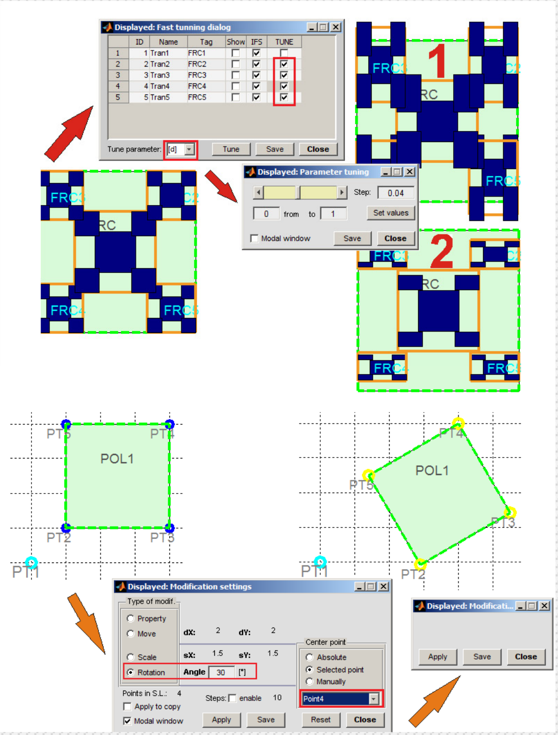

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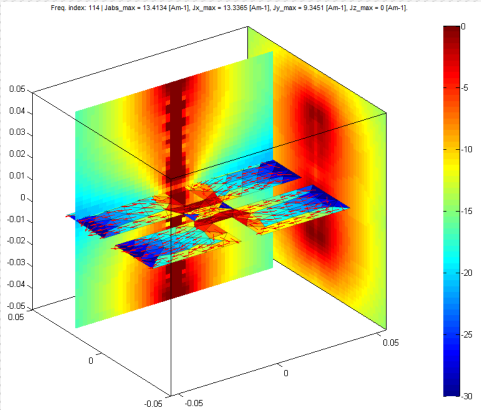

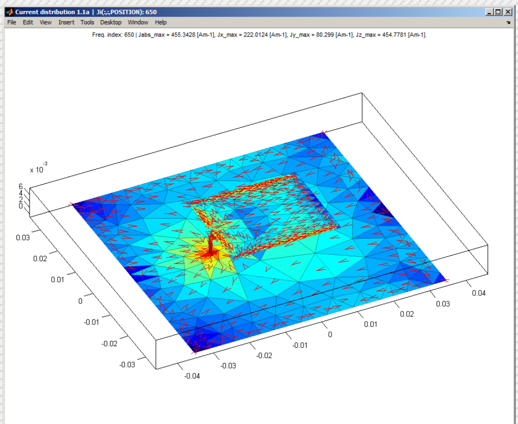

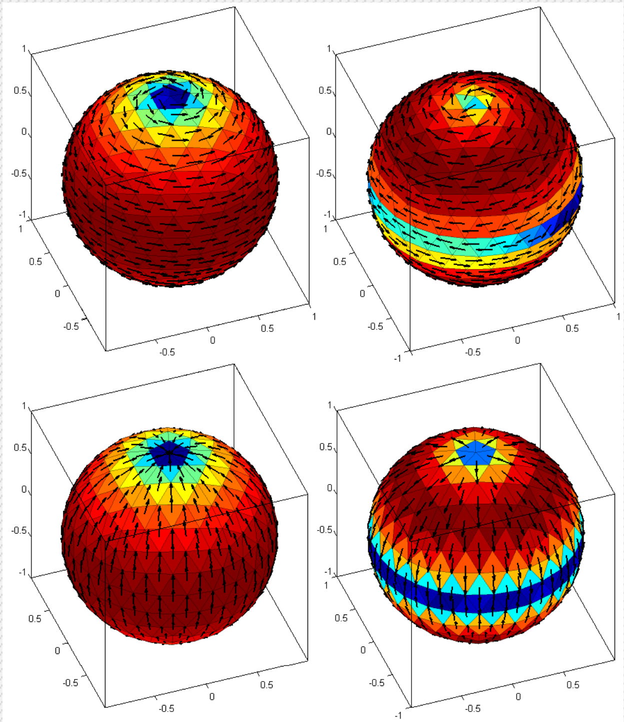

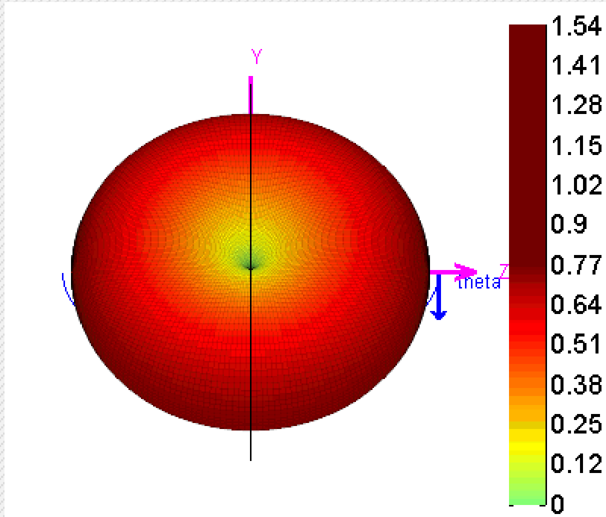

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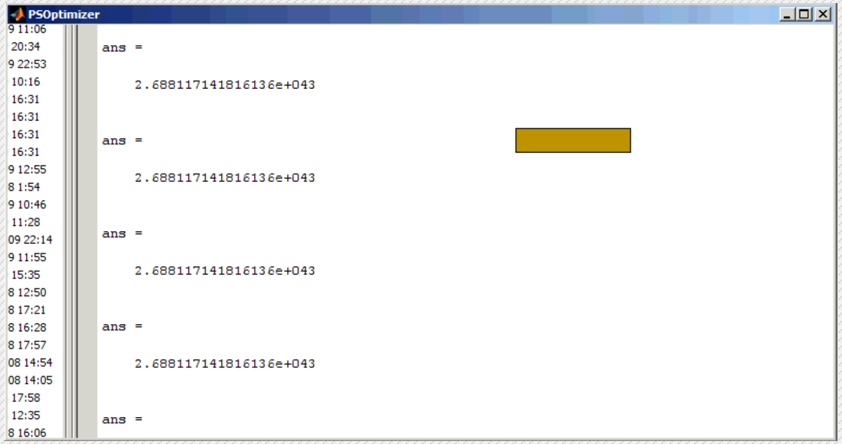
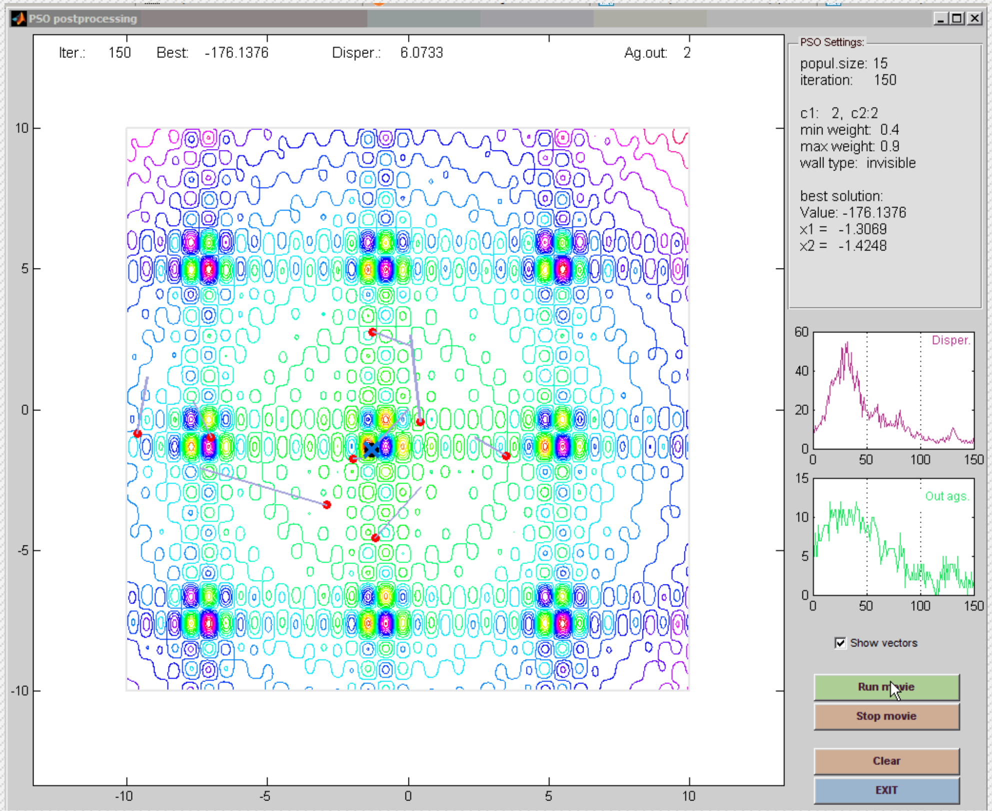
Features

FOPS optimizer

- Single/multicriteria/multidimensional optimization
- Particle Swarm (PSO)
- Self Organizing Migrating Alg. (SOMA)





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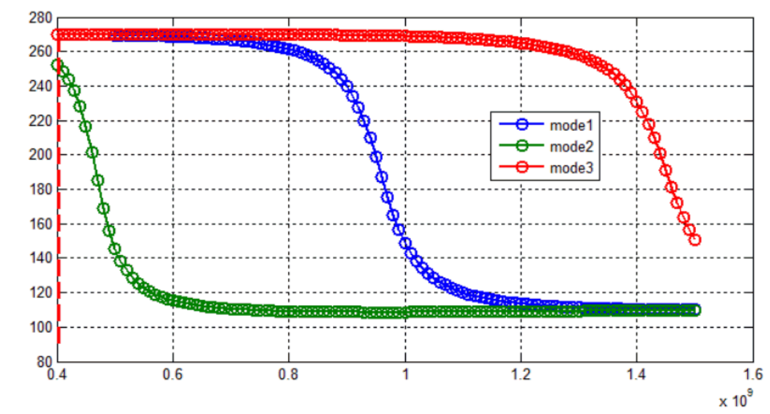

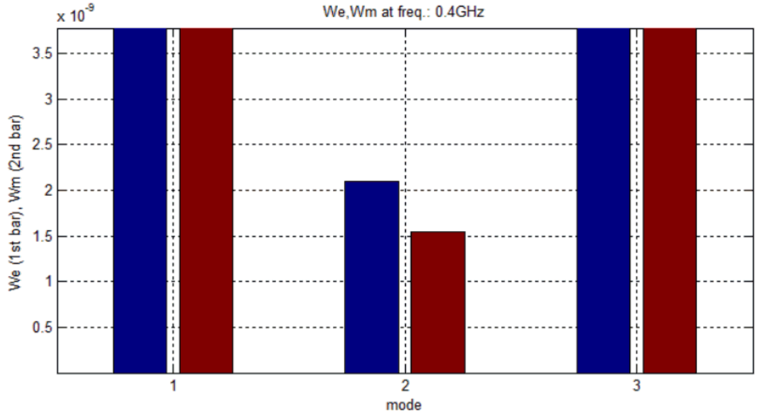

Measurable stored energies

Input impedance expressed in current density

$$Z = \frac{j30}{k|I|^2} \iint\limits_{VV\prime} [k^2 \boldsymbol{J}(\boldsymbol{r}) \cdot \boldsymbol{J}(\boldsymbol{r}')^* - \nabla \cdot \boldsymbol{J}(\boldsymbol{r}) \nabla \cdot \boldsymbol{J}(\boldsymbol{r}')^*] \frac{e^{-jkR}}{R} dV dV'$$

Analytical derivation produces three energy terms

$$\frac{\partial Z}{\partial k} = \widehat{W}_{me} + \widehat{W}_r + \widehat{W}_k$$

$$Q_Z = \frac{\omega}{2R}\left|\frac{\partial Z}{\partial \omega}\right| = \frac{k}{2R}\left|\widehat{W}_{me} + \widehat{W}_r + \widehat{W}_k\right|$$

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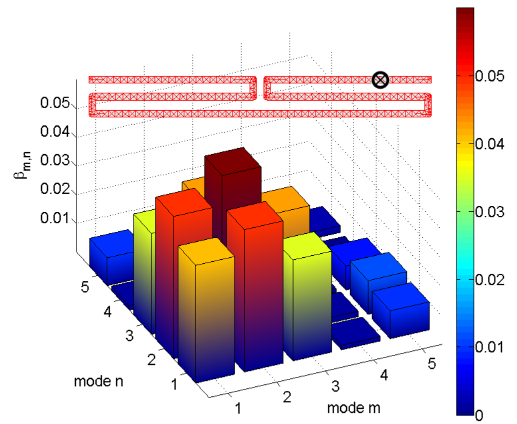

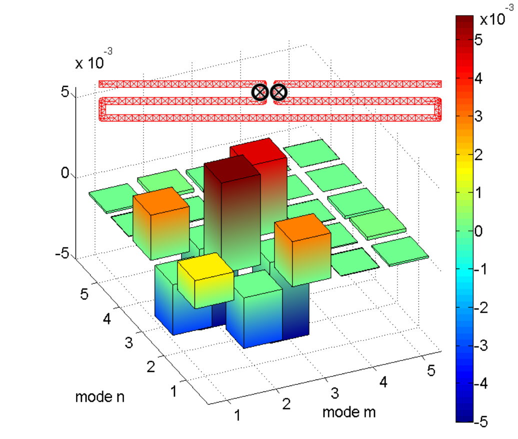

Example of feeding synthesis

$$\boldsymbol{J} = \boldsymbol{Z}^{-1}\boldsymbol{E}^{i} = \sum_{n=1}^{N} \frac{\langle \boldsymbol{J}_n, \boldsymbol{E}^{i} \rangle}{1 + j\lambda_n} \boldsymbol{J}_n = \sum_{n=1}^{N} \alpha_n \boldsymbol{J}_n$$

Modal currents $\boldsymbol{J}_n$ → modal radiated powers and stored energies

For given structure, total quantities depend only on position of feeding point(s) and excitation coefficients. The situation can be described by matrix equations with self and mutual powers and energies

$$\text{Total radiated power} = \text{Trace}\{[\beta_{mn}] \circ [P_{mn}]\}$$

The β matrix represents coupling of external world to the antenna modes

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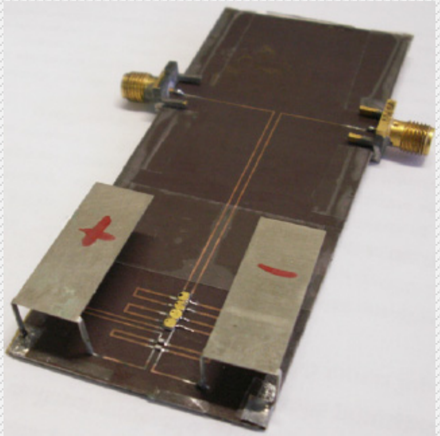
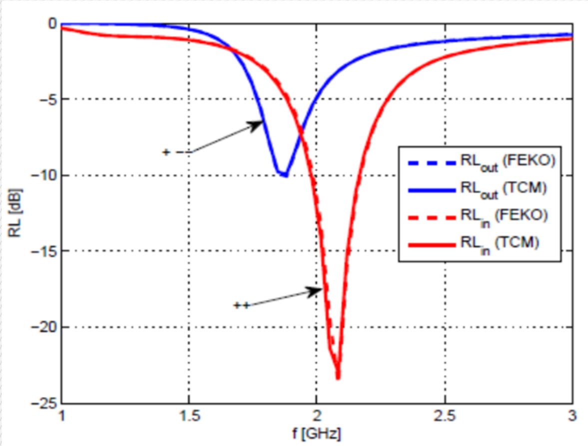
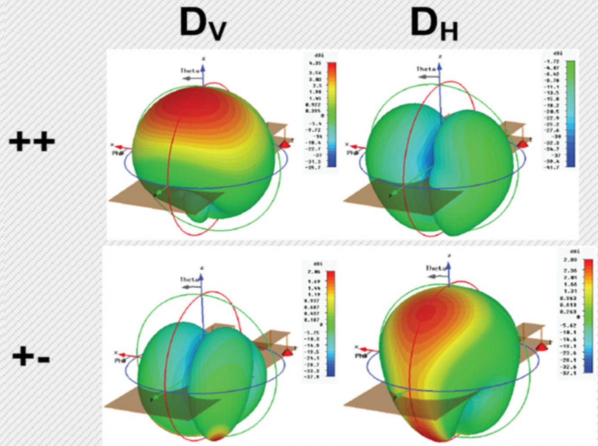
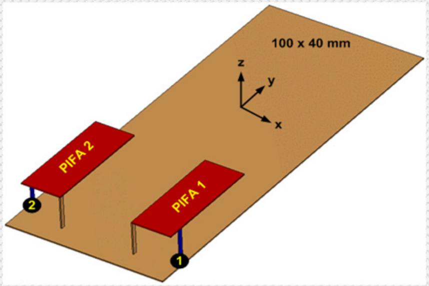
Modal decomposition of dual-PIFA with polarization diversity

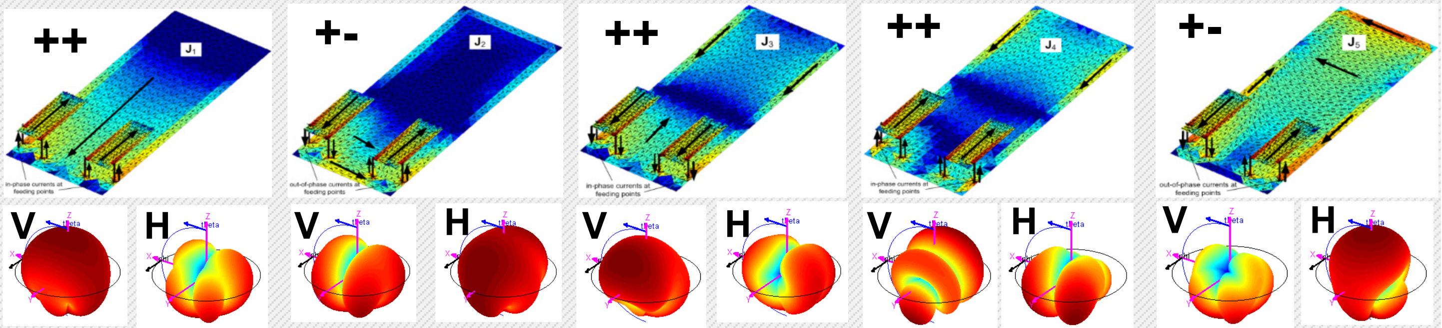






Design by Cyril Luxey





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THANK YOU

FOR YOUR ATTENTION

- Capek, M., Hazdra, P., Eichler, J., "A Method for the Evaluation of Radiation Q Based On Modal Approach," IEEE Trans. Antennas Propag., vol 60, no. 10, p. 4556–4567, 2012.
- Capek, M., Hamouz, P., Hazdra, P., Eichler, J., "Implementation of the Theory of Characteristic Modes in Matlab," IEEE Antennas Propag. Magazine, vol 55, no. 2, p. 176–189, 2013.
- Capek, M., Eichler, J., Hazdra, P., “Evaluating Radiation Efficiency from Characteristic Currents," IET-MAP, vol 9, no. 1, p. 10–15, 2015.

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