



# AToM

ANTENNA TOOLBOX FOR MATLAB

DEPARTMENT OF ELECTROMAGNETIC FIELD  
CZECH TECHNICAL UNIVERSITY IN PRAGUE  
CZECH REPUBLIC



**AToM**  
ANTENNA TOOLBOX FOR MATLAB

CZECH TECHNICAL UNIVERSITY IN PRAGUE  
DEPARTMENT OF ELECTROMAGNETIC FIELD  
TECHNICKA 2, 166 27 PRAHA 6, CZECH REPUBLIC

# Antenna Toolbox for Matlab (AToM)

M. Čapek<sup>1</sup>, V. Adler<sup>1</sup>, V. Losenický<sup>1</sup>,  
M. Mašek<sup>1</sup>, F. Kozák<sup>1</sup>, P. Hazdra<sup>1</sup>,  
P. Kadlec<sup>2</sup>, V. Šeděnka<sup>2</sup>, M. Marek<sup>2</sup>,  
J. Rýmús<sup>3</sup>

<sup>1</sup> Czech Technical University in Prague, <sup>2</sup> Brno University of Technology,  
<sup>3</sup> MECAS ESI s.r.o.

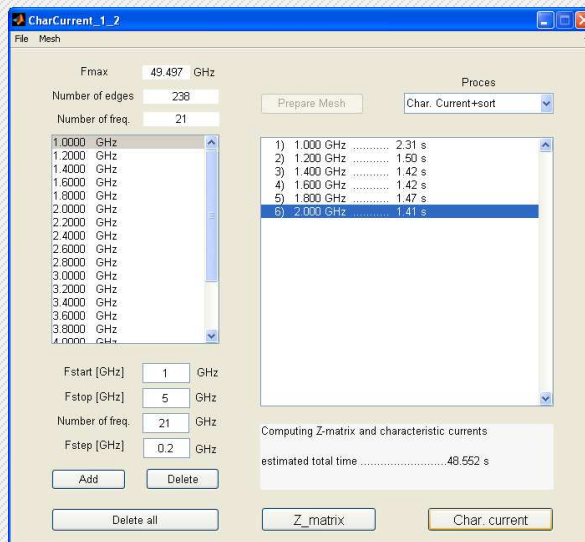
[viktor.adler@antennatoolbox.com](mailto:viktor.adler@antennatoolbox.com)



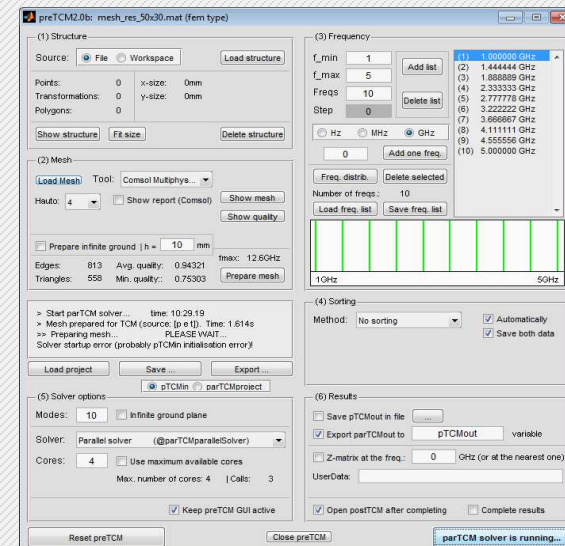
# History of the toolbox

- 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





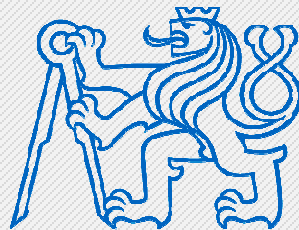
**AToM**  
ANTENNA TOOLBOX FOR MATLAB

CZECH TECHNICAL UNIVERSITY IN PRAGUE  
DEPARTMENT OF ELECTROMAGNETIC FIELD  
TECHNICKA 2, 166 27 PRAHA 6, CZECH REPUBLIC

# Tools for Synthesis of Antennas and Sensors

## Project details

- supported by Technology Agency of the Czech Republic (TA ČR)
  - ALFA programme (applied research, experimental development, technologies)
  - time of development: 07/2014 - 12/2017
  - approx. 600 k€
- 3 participants
  - CTU in Prague and BUT - AToM and FOPS (Matlab)
  - MECAS ESI s.r.o. - Visual Antenna (CEM One)





# Tools for Synthesis of Antennas and Sensors

## Project details

- project's staff

- Miloslav Capek, Viktor Adler, Milos Mazanek, Pavel Hazdra, Petr Kadlec, Vladimir Sedenka, Zbynek Raida, Jaroslav Rymus



- students

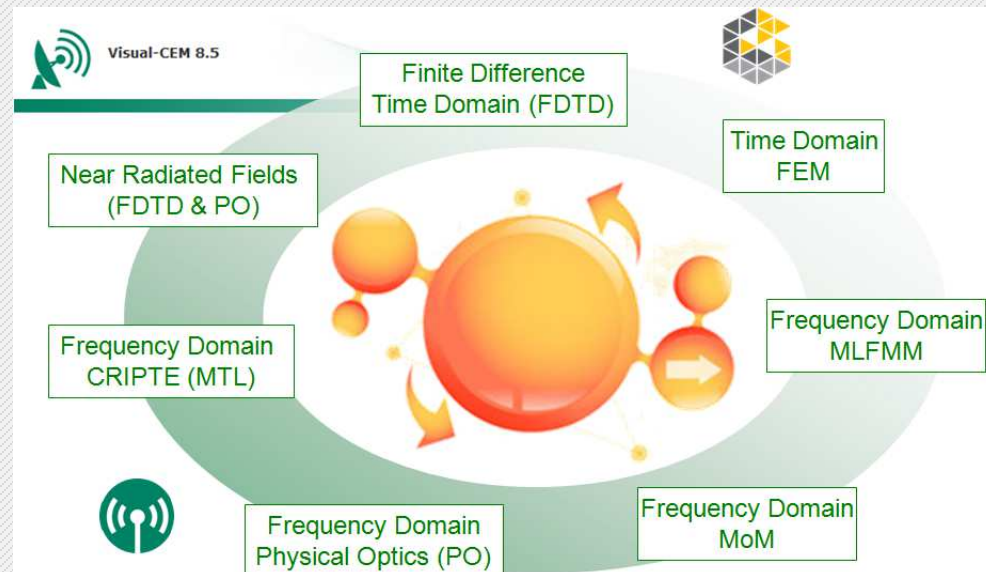
- Vit Losenicky, Michal Masek, Miroslav Cupal, Martin Marek, Martin Strambach





# AToM → Visual Antenna

- The key functionality of the AToM will be implemented into Visual Antenna package, developed by MECAS ESI company.
- Visual Antenna is a module for CEM One, which integrates simulation tools for Computational Electromagnetics developer and distributed worldwide by ESI Group





# Antenna Toolbox for Matlab

## Main features

- method of moments for 3D planar and wire structures
- characteristic mode decomposition with robust tracking
- adaptive frequency sweep
- accept other codes from the community - semiopen MATLAB architecture
- handle with data from third party software
- utilization of the ***source concept*** → ***antenna can be completely described by its geometry and current density***

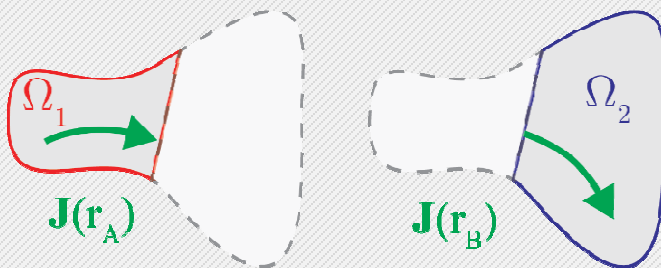




# Antenna Toolbox for Matlab

## Main features

- method of moments for 3D planar and wire structures
- characteristic mode decomposition with robust tracking
- adaptive frequency sweep
- accept other codes from the community - semiopen MATLAB architecture
- handle with data from third party software
- utilization of the **source concept** → **antenna can be completely described by its geometry and current density**



Structural decomposition





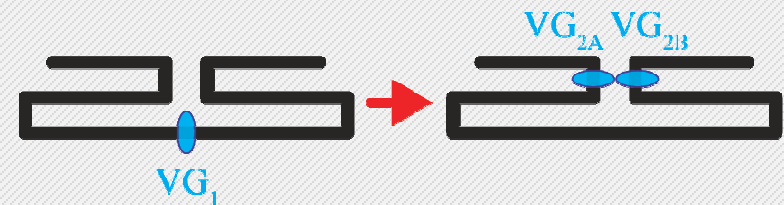
# Antenna Toolbox for Matlab

## Main features

- method of moments for 3D planar and wire structures
- characteristic mode decomposition with robust tracking
- adaptive frequency sweep
- accept other codes from the community - semiopen MATLAB architecture
- handle with data from third party software
- utilization of the **source concept** → **antenna can be completely described by its geometry and current density**



Structural decomposition



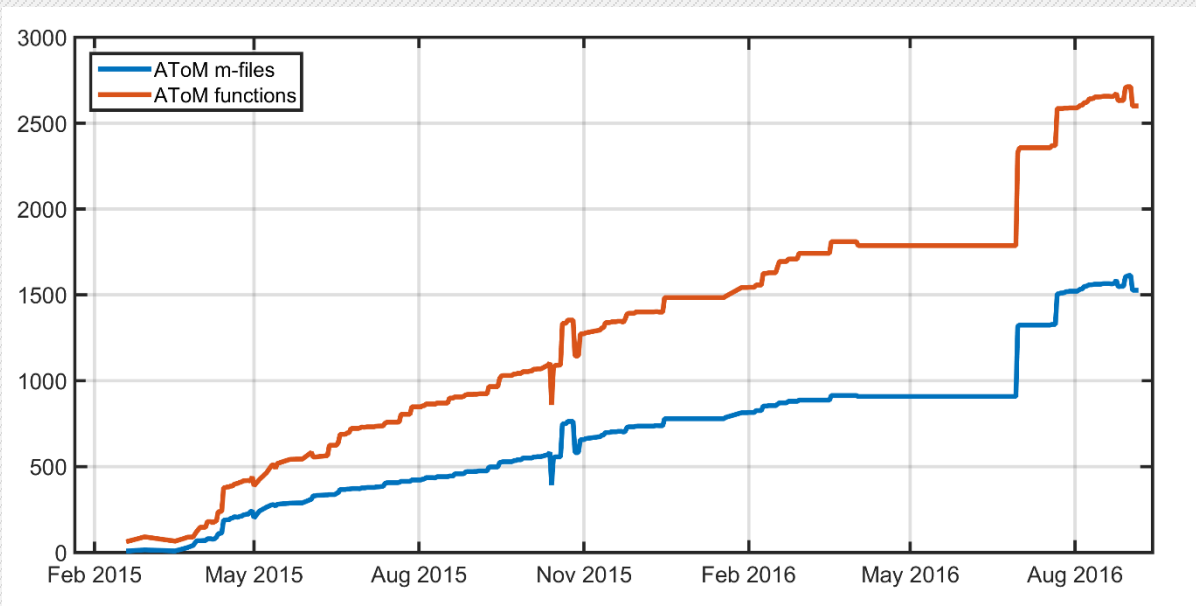
Feeding synthesis



# Antenna Toolbox for Matlab

## Present state

- data analyzed daily at GIT server by Jenkins



|               |       |
|---------------|-------|
| classes       | 197   |
| functions     | 2603  |
| m-files       | 1540  |
| unit tests    | 1224  |
| lines of code | 98106 |
| comments      | 10235 |

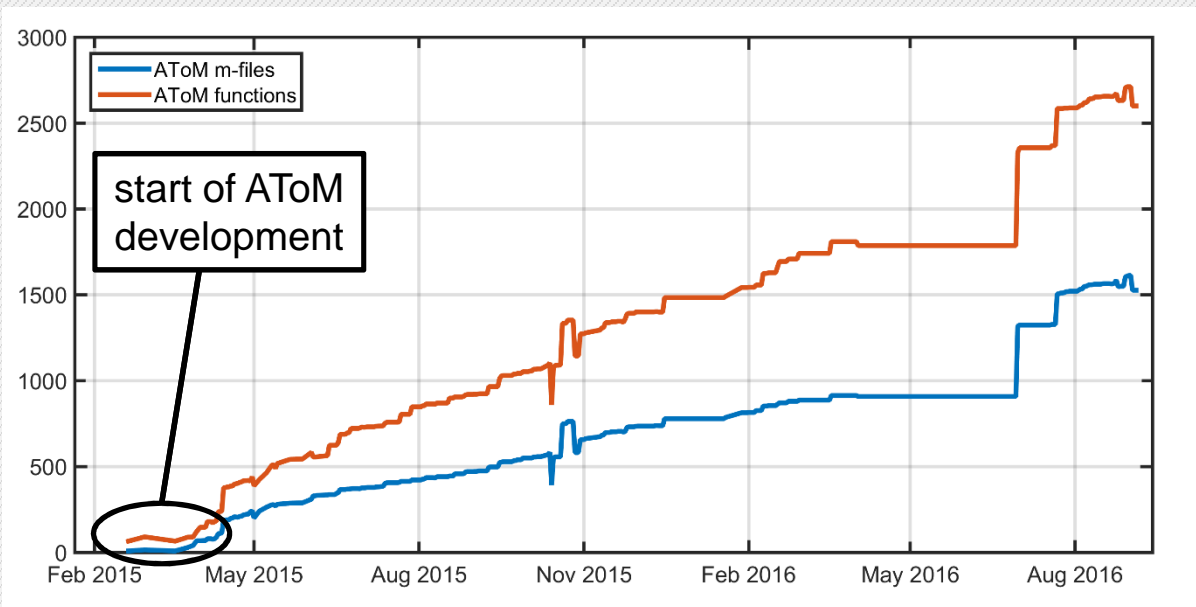
Valid on 05/09/2016.



# Antenna Toolbox for Matlab

## Present state

- data analyzed daily at GIT server by Jenkins



|               |       |
|---------------|-------|
| classes       | 197   |
| functions     | 2603  |
| m-files       | 1540  |
| unit tests    | 1224  |
| lines of code | 98106 |
| comments      | 10235 |

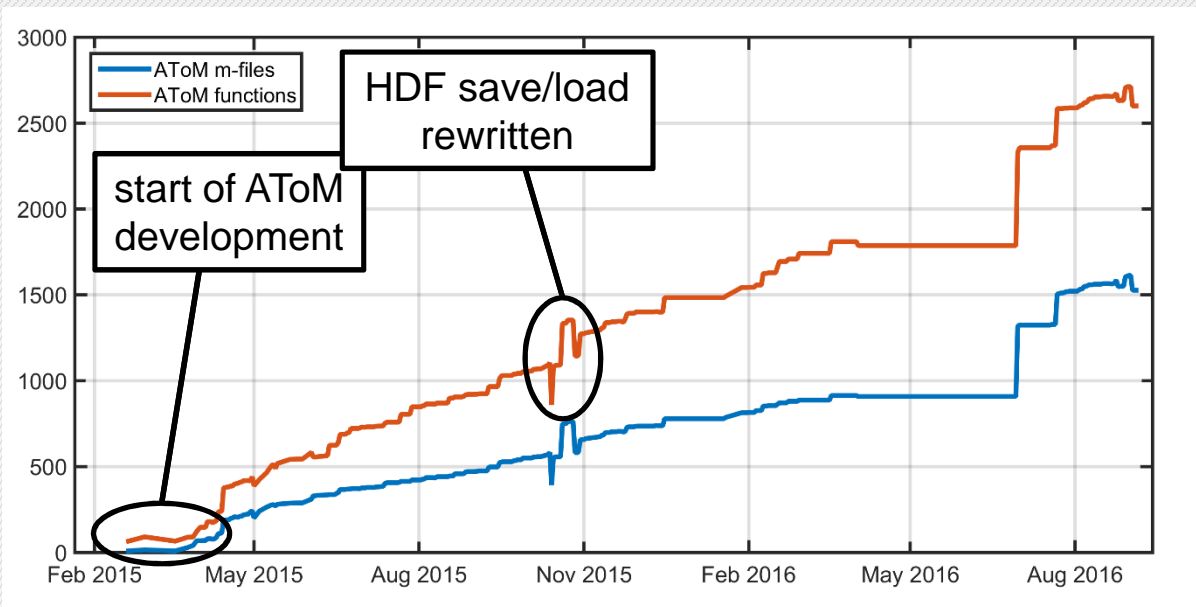
Valid on 05/09/2016.



# Antenna Toolbox for Matlab

## Present state

- data analyzed daily at GIT server by Jenkins



|               |       |
|---------------|-------|
| classes       | 197   |
| functions     | 2603  |
| m-files       | 1540  |
| unit tests    | 1224  |
| lines of code | 98106 |
| comments      | 10235 |

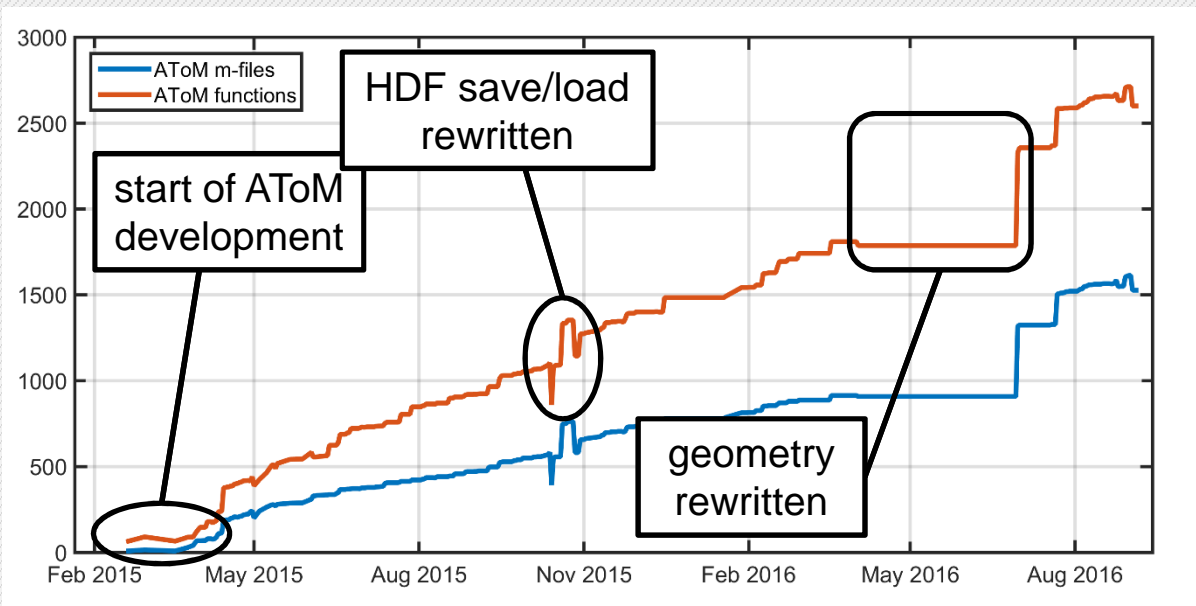
Valid on 05/09/2016.



# Antenna Toolbox for Matlab

## Present state

- data analyzed daily at GIT server by Jenkins



|               |       |
|---------------|-------|
| classes       | 197   |
| functions     | 2603  |
| m-files       | 1540  |
| unit tests    | 1224  |
| lines of code | 98106 |
| comments      | 10235 |

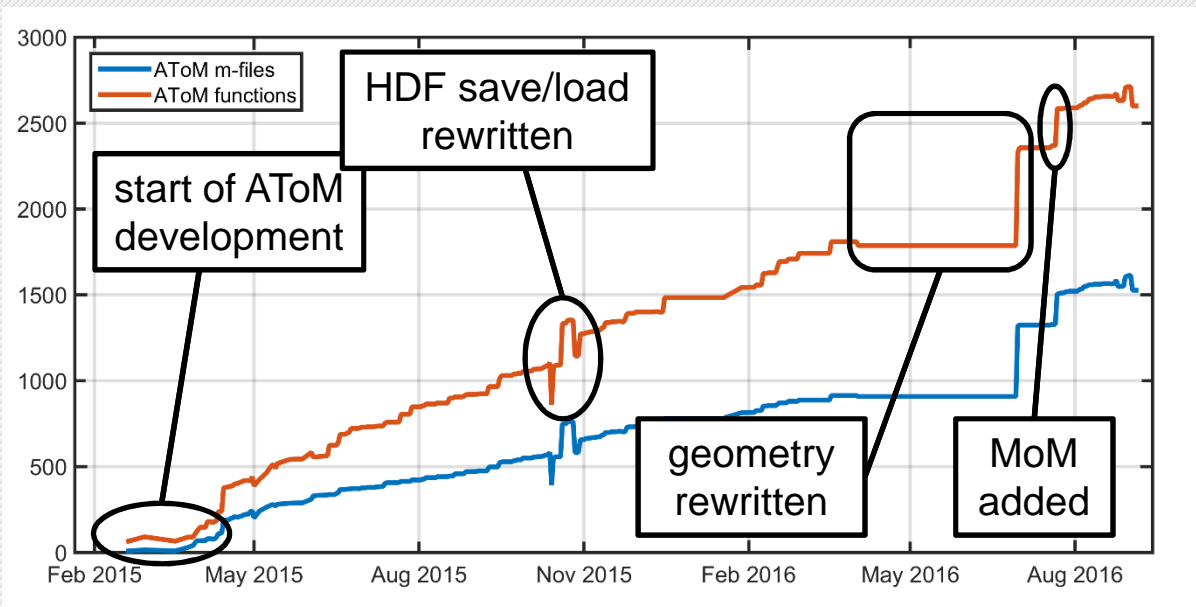
Valid on 05/09/2016.



# Antenna Toolbox for Matlab

## Present state

- data analyzed daily at GIT server by Jenkins



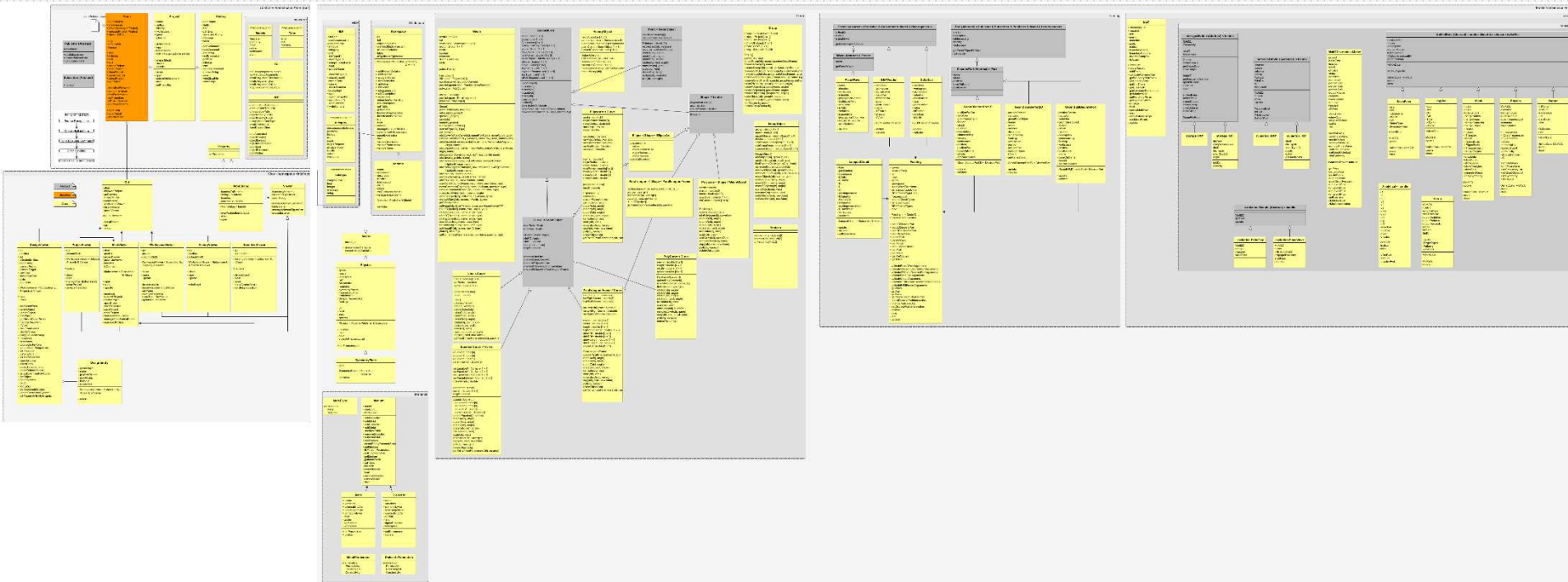
|               |       |
|---------------|-------|
| classes       | 197   |
| functions     | 2603  |
| m-files       | 1540  |
| unit tests    | 1224  |
| lines of code | 98106 |
| comments      | 10235 |

Valid on 05/09/2016.



# Antenna Toolbox for Matlab

UML scheme at 04/2016









# Antenna Toolbox for Matlab

## Project infrastructure

- CTU server in Prague
  - Jenkins - continuous integration system
  - Unit Test Framework
  - analyze whole code once a day
  - iceScrum (SCRUM)
  - results are saved to ftp
  - sending emails to sinners



# Jenkins

```
ans =  
  
1x1224 TestResult array with properties:  
  
    Name  
    Passed  
    Failed  
    Incomplete  
    Duration  
  
Totals:  
    1224 Passed, 0 Failed, 0 Incomplete.  
    397.3271 seconds testing time.  
fx >>
```



# Antenna Toolbox for Matlab

## Main classes

- Atom
  - singleton pattern utilized
  - management of projects
  - handling with preferences
- Project
  - contain references to all models
  - practically no functionality
- HDF
  - data storage
  - Hierarchical Data Format
  - suitable for recording and recovering computer data of electromagnetic simulations



# Antenna Toolbox for Matlab

## Main classes

- Atom
  - singleton pattern utilized
  - management of projects
  - handling with preferences
- Project
  - contain references to all models
  - practically no functionality
- HDF
  - data storage
  - Hierarchical Data Format
  - suitable for recording and recovering computer data of electromagnetic simulations

```
atom = Atom.start;  
atom.createProject('myProject');  
atom.selectedProject.save;  
atom.closeProject('myProject');  
atom.openProject('myProject');  
atom.quit;
```



# Antenna Toolbox for Matlab

## Main classes

- History
  - all actions in AToM are captured
  - overloaded `subsref` of Project
  - actions can be evaluated as batch
- Workspace
  - using variables through AToM
  - arbitrary complex expressions
  - calling external functions from AToM
  - observer pattern utilized



# Antenna Toolbox for Matlab

## Main classes

- History
  - all actions in AToM are captured
  - overloaded `subsref` of Project
  - actions can be evaluated as batch
- Workspace
  - using variables through AToM
  - arbitrary complex expressions
  - calling external functions from AToM
  - observer pattern utilized

```
History - Minkowski_fractal
No. Command
13 atom.selectedProject.solver.BEM.setProperties('tolerance', 1e-10);
12 atom.selectedProject.solver.MoM.setup.setProperties('hdfCompressionL...
11 atom.selectedProject.mesh.setProperties('meshOnFly', 0);
10 atom.selectedProject.mesh.setProperties('nPointsOnEllipseArc', 500000);
9 atom.selectedProject.mesh.setProperties('nPointsOnEquationCurve', 50...
8 atom.selectedProject.mesh.setProperties('tolerance', 1e-10);
7 atom.selectedProject.geom.setProperties('nPointsOnCurve', 73);
6 atom.selectedProject.geom.setProperties('tolerance', 1e-10);
5 atom.selectedProject.workspace.setProperties('nSignificantDigitsView...
4 % automatically set during carrying out of createProject method
3 %% Preferences setting #begining
2 atom.createProject('Minkowski_fractal');
1 atom = Atom.start(false);
```

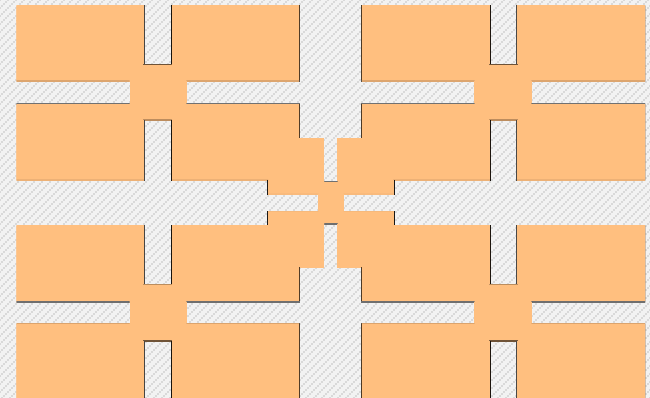


# Antenna Toolbox for Matlab

## Main classes

- History
  - all actions in AToM are captured
  - overloaded `subsref` of Project
  - actions can be evaluated as batch
- Workspace
  - using variables through AToM
  - arbitrary complex expressions
  - calling external functions from AToM
  - observer pattern utilized

| No. | Command                                                                    |
|-----|----------------------------------------------------------------------------|
| 13  | atom.selectedProject.solver.BEM.setProperties('tolerance', 1e-10);         |
| 12  | atom.selectedProject.solver.MoM.setup.setProperties('hdfCompressionL...'); |
| 11  | atom.selectedProject.mesh.setProperties('meshOnFly', 0);                   |
| 10  | atom.selectedProject.mesh.setProperties('nPointsOnEllipseArc', 500000);    |
| 9   | atom.selectedProject.mesh.setProperties('nPointsOnEquationCurve', 50...);  |
| 8   | atom.selectedProject.mesh.setProperties('tolerance', 1e-10);               |
| 7   | atom.selectedProject.geom.setProperties('nPointsOnCurve', 73);             |
| 6   | atom.selectedProject.geom.setProperties('tolerance', 1e-10);               |
| 5   | atom.selectedProject.workspace.setProperties('nSignificantDigitsView...'); |
| 4   | % automatically set during carrying out of createProject method            |
| 3   | %% Preferences setting #beginning                                          |
| 2   | atom.createProject('Minkowski_fractal');                                   |
| 1   | atom = Atom.start(false);                                                  |







# Antenna Toolbox for Matlab

## Main classes

- Geom
  - definition of geometry primitives
  - transformations, boolean operations
  - parametrization of design
  
- Mesh
  - creation of deterministic mesh from geometry
  - using DistMesh - P. O. Persson
  - fix points and fix edges

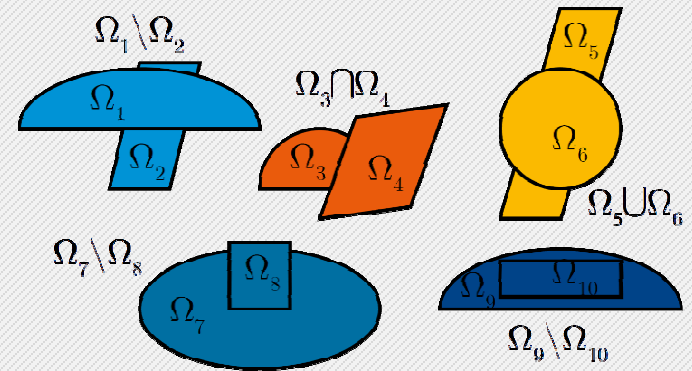


# Antenna Toolbox for Matlab

## Main classes

- Geom

- definition of geometry primitives
- transformations, boolean operations
- parametrization of design



- Mesh

- creation of deterministic mesh from geometry
- using DistMesh - P. O. Persson
- fix points and fix edges

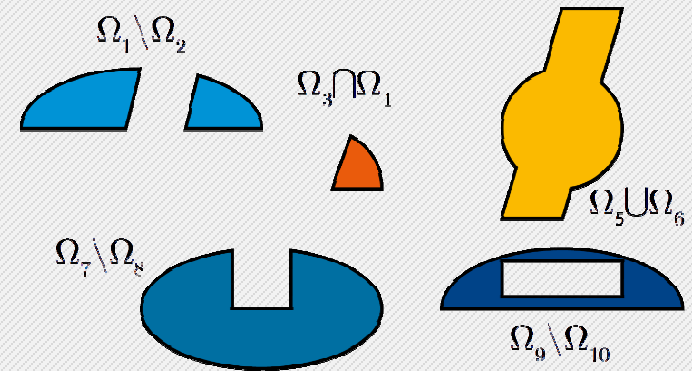


# Antenna Toolbox for Matlab

## Main classes

- Geom

- definition of geometry primitives
- transformations, boolean operations
- parametrization of design



- Mesh

- creation of deterministic mesh from geometry
- using DistMesh - P. O. Persson
- fix points and fix edges



# Antenna Toolbox for Matlab

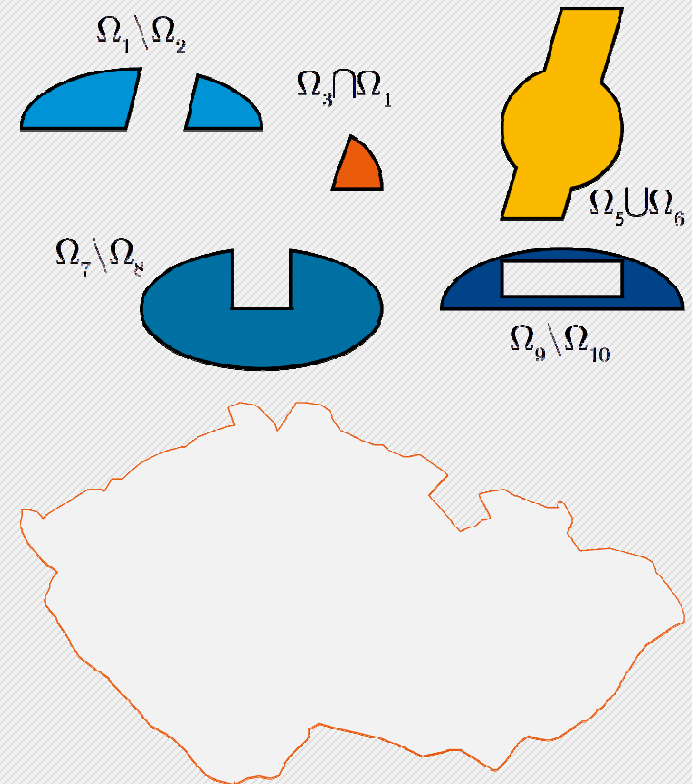
## Main classes

- Geom

- definition of geometry primitives
- transformations, boolean operations
- parametrization of design

- Mesh

- creation of deterministic mesh from geometry
- using DistMesh - P. O. Persson
- fix points and fix edges



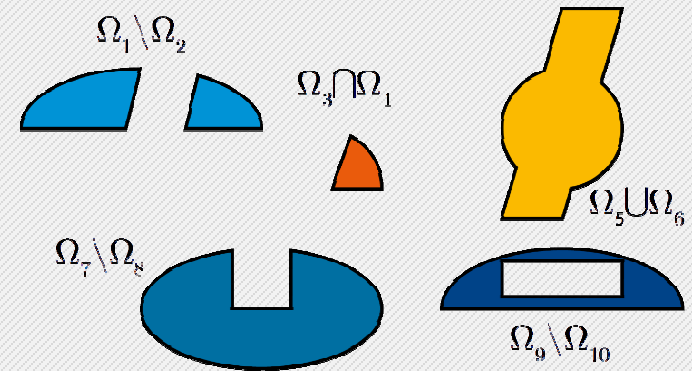


# Antenna Toolbox for Matlab

## Main classes

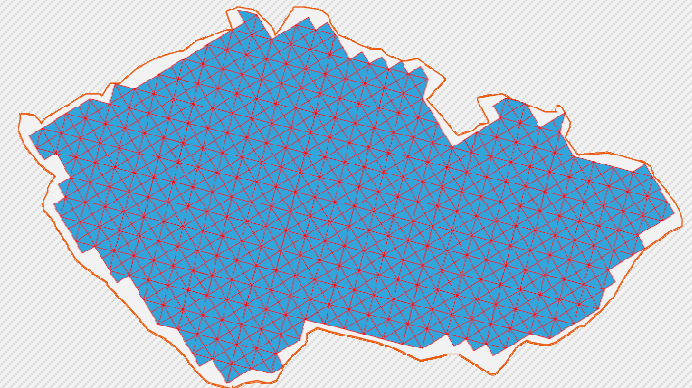
- Geom

- definition of geometry primitives
- transformations, boolean operations
- parametrization of design



- Mesh

- creation of deterministic mesh from geometry
- using DistMesh - P. O. Persson
- fix points and fix edges





# Antenna Toolbox for Matlab

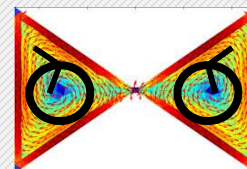
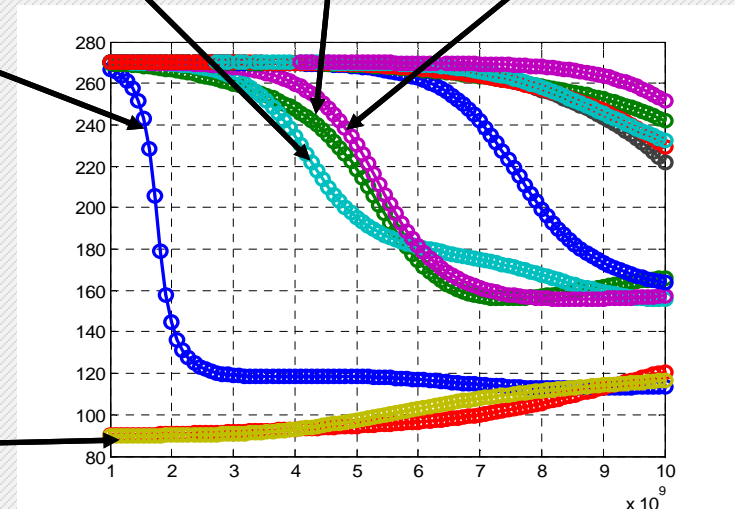
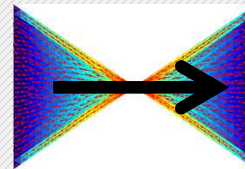
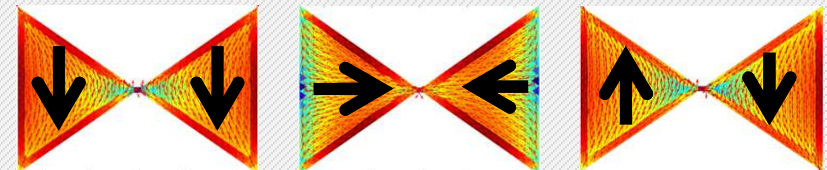
## Main classes

- Physics

- physical parameters of design
- frequency list
- feeding
- symmetry planes
- boundary conditions

- Solvers

- MoM (Method of Moments) 1D and 2D
- GEP (General Eigenvalue Problem)
- BEM (Boundary Elements Method)







# Antenna Toolbox for Matlab GUI

- Observer pattern utilized

The screenshot displays the AToM GUI interface. The main window shows a 3D visualization of a fractal antenna structure, rendered as a red mesh. The structure consists of multiple parallel, zig-zagging lines. The workspace window on the right contains a table with the following data:

| Name   | Expression     | Description | Value            | Class  | Size   | Status |
|--------|----------------|-------------|------------------|--------|--------|--------|
| 1 IFS  | sample.g...    |             | 4x2x25 double    | double | 4x2x25 | OK     |
| 2 pts  | {-50 -30;18... |             | {-50 -30;50 ...  | double | 4x2    | OK     |
| 3 trns | {0.2000000...  |             | {0.2 0 0 0.33... | double | 5x6    | OK     |
| 4      |                |             |                  |        |        |        |

The command history window at the bottom right shows a list of commands, including:

```
72 atom.selectedProject.mesh.getMesh;  
71 atom.selectedProject.mesh.setMeshSize('Parallelogram', 2);  
70 atom.selectedProject.mesh.setProperties('animation2D', true);  
69 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
68 atom.selectedProject.geom.addParallelogram([-50 -31.450000000000003 0...  
67 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
66 atom.selectedProject.geom.addParallelogram([-50 3.649999999999999 0]...  
65 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
64 atom.selectedProject.geom.addParallelogram([5 -31.450000000000003 0]...  
63 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
62 atom.selectedProject.geom.addParallelogram([5 3.649999999999999 0]...  
61 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
60 atom.selectedProject.geom.addParallelogram([-10 -10.333333333333332 0]...  
59 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
58 atom.selectedProject.geom.addParallelogram([-50 -15.699999999999999 0]...  
57 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
56 atom.selectedProject.geom.addParallelogram([-50 15.300000000000001 0]...  
55 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
54 atom.selectedProject.geom.addParallelogram([5 -15.699999999999999 0]...  
53 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
52 atom.selectedProject.geom.addParallelogram([5 15.300000000000001 0]...  
51 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
50 atom.selectedProject.geom.addParallelogram([-10 1.333333333333333 0]...  
49 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
48 atom.selectedProject.geom.addParallelogram([-25 25 -31.450000000000000...  
47 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
46 atom.selectedProject.geom.addParallelogram([-25 25 3.649999999999999...  
45 atom.selectedProject.geom.boolean.unite('Parallelogram', 'Parallelog...  
44 atom.selectedProject.geom.addParallelogram([29.75 -31.450000000000003...  
43 atom.selectedProject.geom.addParallelogram([29.75 3.649999999999999...  
42 atom.selectedProject.geom.addParallelogram([29.75 3.649999999999999...
```





# Antenna Toolbox for Matlab

## Utilized Matlab features

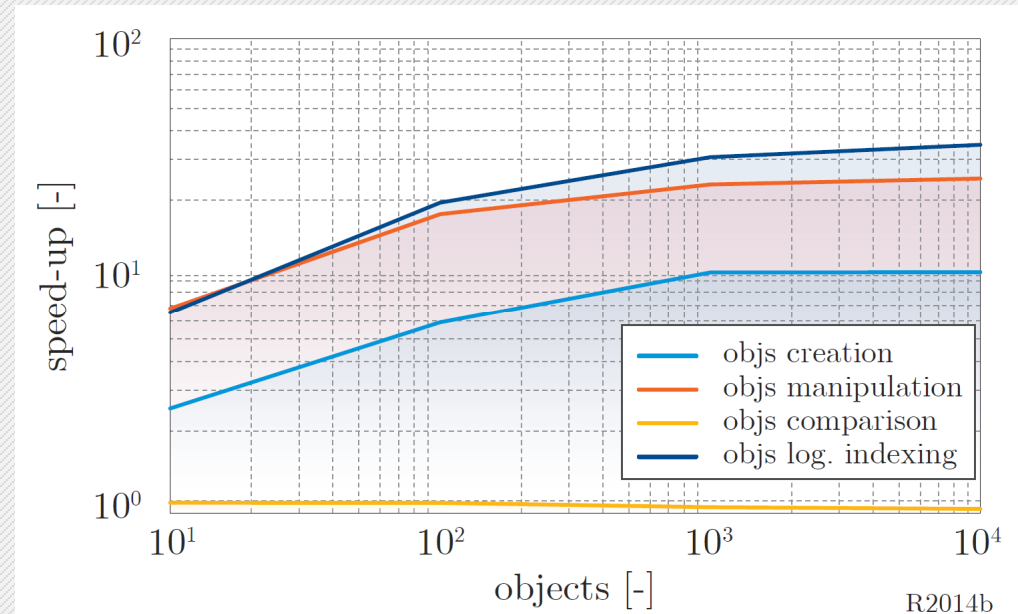
- Object-Oriented Programming
  - vectorized OOP
  - heterogeneous classes
- Unit Test Framework
  - Class-Based Unit Tests
- Source Control Integration
  - GIT
- Code Performance
  - profiling via `profile`
  - profile coverage



# Antenna Toolbox for Matlab

## Utilized Matlab features

- Object-Oriented Programming
  - vectorized OOP
  - heterogeneous classes
- Unit Test Framework
  - Class-Based Unit Tests
- Source Control Integration
  - GIT
- Code Performance
  - profiling via `profile`
  - profile coverage



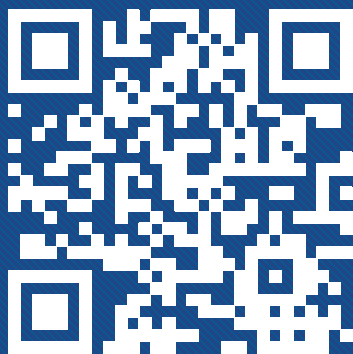


**AToM**  
ANTENNA TOOLBOX FOR MATLAB

CZECH TECHNICAL UNIVERSITY IN PRAGUE  
DEPARTMENT OF ELECTROMAGNETIC FIELD  
TECHNICKA 2, 166 27 PRAHA 6, CZECH REPUBLIC

# THANK YOU

## FOR YOUR ATTENTION



[www.antennatoolbox.com](http://www.antennatoolbox.com)  
[info@antennatoolbox.com](mailto:info@antennatoolbox.com)  
[viktor.adler@antennatoolbox.com](mailto:viktor.adler@antennatoolbox.com)

SUPPORTED BY



**T** VYSOKÉ UČENÍ  
TECHNICKÉ  
V BRNĚ



**VISTA**

