openEMS - An Introduction and Overview

Using an EM field solver to design antennas and PCBs

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Outline

What is openEMS?

- free and open source **electromagnetic field solver**
- can be used to simulate/evaluate **RF and optical devices** (e.g. antennas, filters, waveguides, transmission lines, RCS[1], ...)
- uses the **FDTD**[2] method to iteratively solve Maxwell's equations in time domain
- **Octave/Matlab** (or Python[3]) are used as scripting interface
- **Linux and Windows** fully supported
- the **user has full control** over every aspect of the simulation
- comes with a lot of **tutorials and examples**

[1] Radar cross section
[2] Finite Difference Time Domain
[3] Python interface is not feature complete yet

List of Features

- Full 3D EC-FDTD in **Cartesian and cylindrical coordinates**
- Many geometrical primitives: e.g. cubes, cylinder, wires, polygons...
- Import/Export CAD models (e.g. STL or PLY files)
- **Lumped elements like SMD resistors, capacitors and inductances**
- **Builtin simple circuit simulation or touchstone export**
- Coordinate dependent material and excitation definition
- Support for multi-polar dispersive material model
- Include human body models (e.g. Virtual Family)
- Access and process raw or interpolated field dumps in TD or FD
- Fast multi-threading, near-to-far-field transformation
- Simple graphical user interface to review the defined structures
- FDTD engine utilizing SSE, multi-threading and operator compression
- Support for remote/cloud or cluster (MPI) computing
- ...

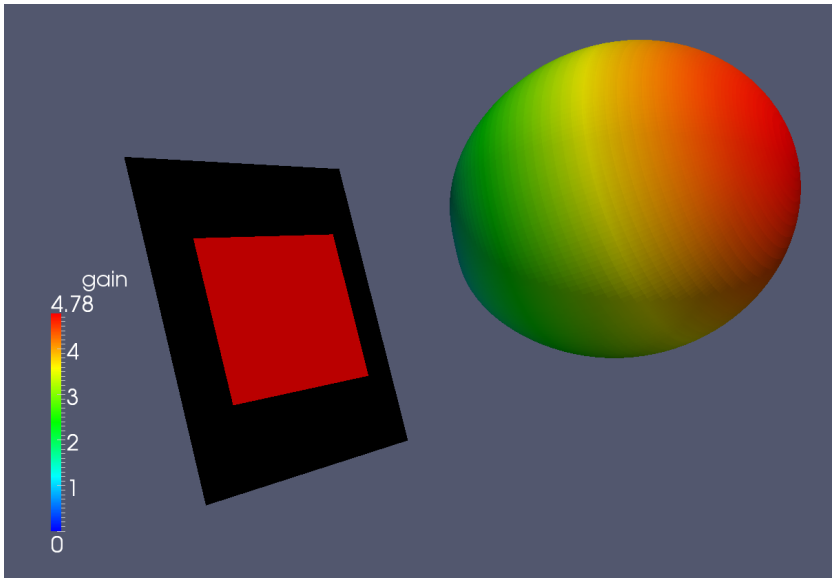
A typical openEMS Simulation Script

- Header part with constants and defines
- General FDTD setup like:
  - TD pulse setup (typically Gaussian pulse)
  - Boundary conditions
- CAD Part:
  - Define substrates/materials and metallic objects
  - Define lumped elements & (lumped) ports (active and passive)
- Setup the FDTD mesh:
  - Most important step
  - Needs the most experience!
- Setup field dumps (near- or far-field)
- **Run the simulation**
- Post-processing and figure creation

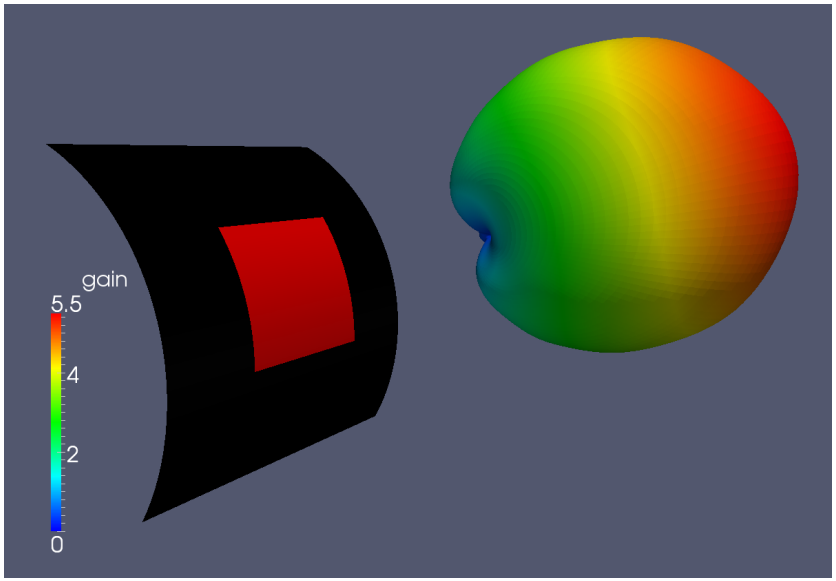
Time for an example!

Simple Patch Antenna Examples

Tutorial: Wifi (2.4 GHz) patch antenna example



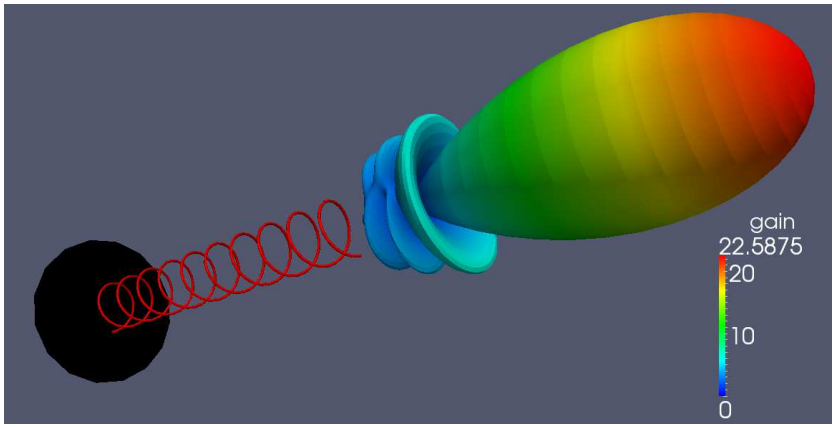
(a) Conventional / Cartesian Patch Antenna



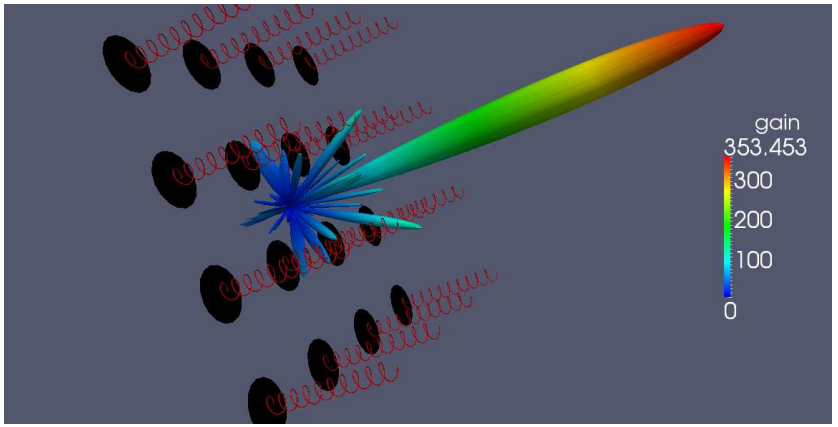
(b) Conformal / Cylindrical Patch Antenna

Helical Antenna Examples

Tutorial: Wifi helical antenna example:



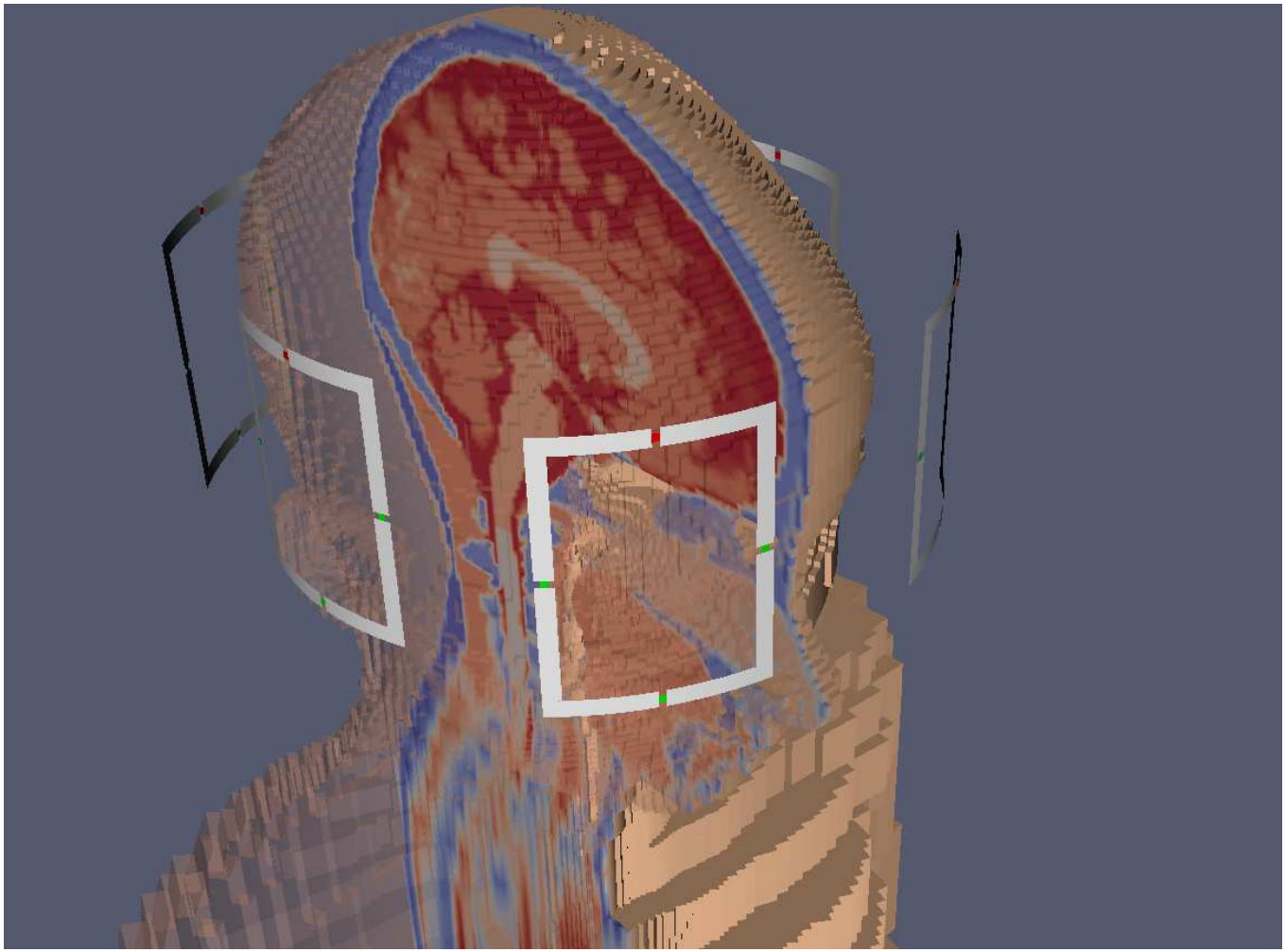
(a) Helical Antenna using a Cartesian or Cylindrical grid



(b) Helical Antenna Array using a Cartesian grid

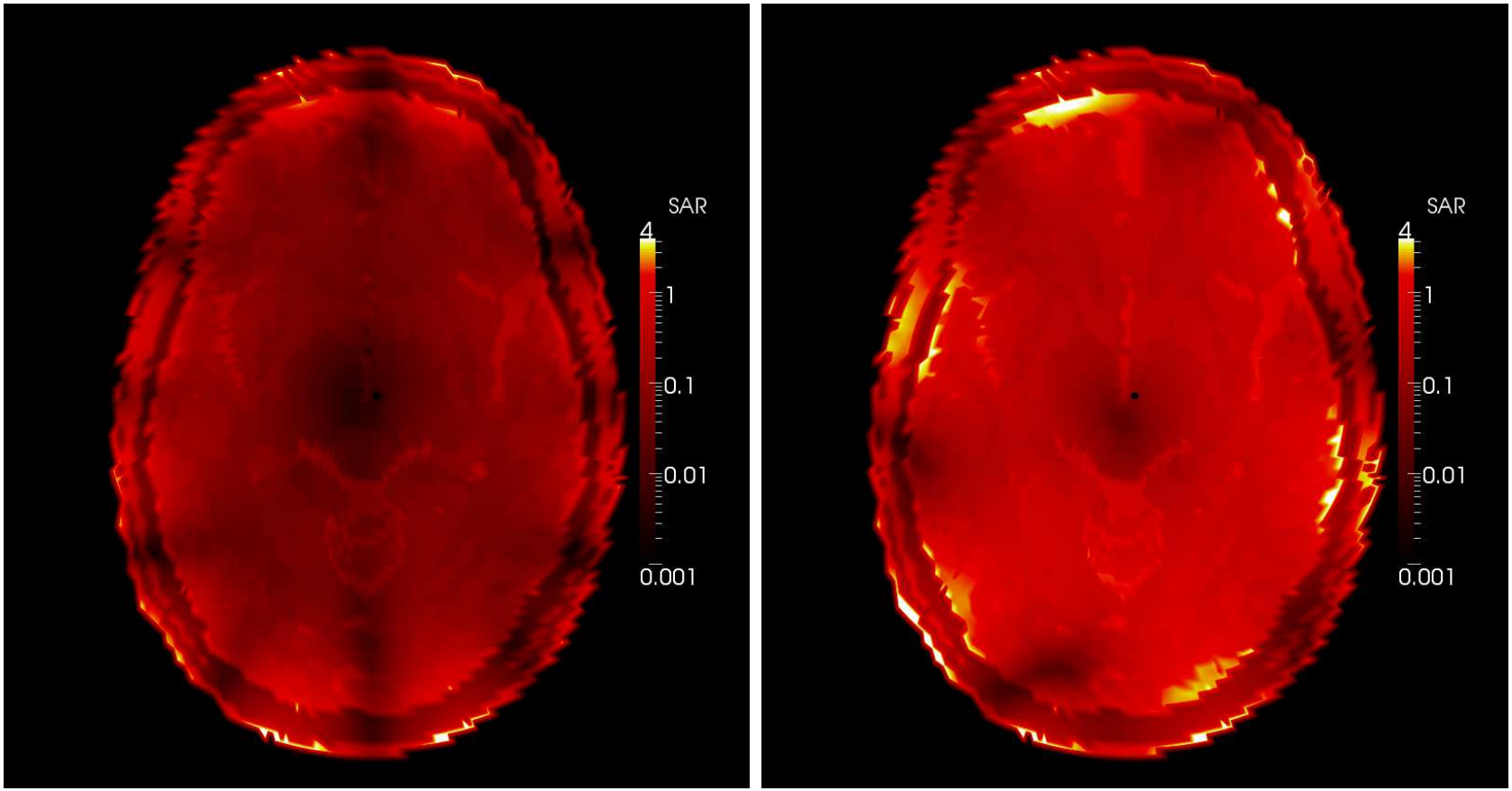
MRI: Multi Transmit SAR Calculation Example I

6 Loop Coils



MRI: Multi Transmit SAR Calculation Example II

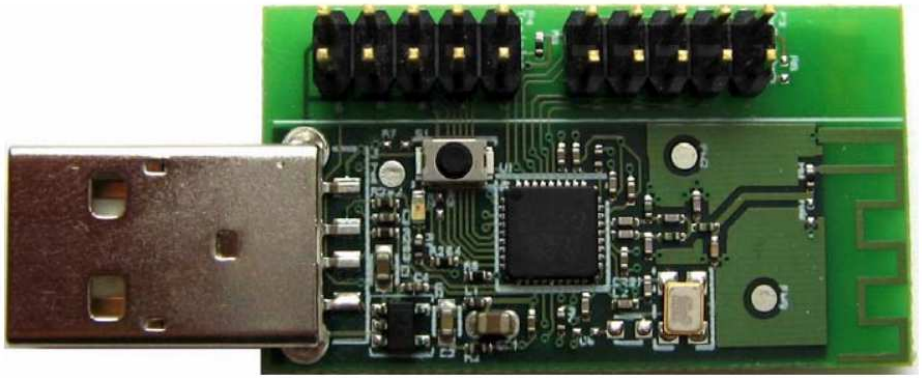
Multi transmit local SAR examples:



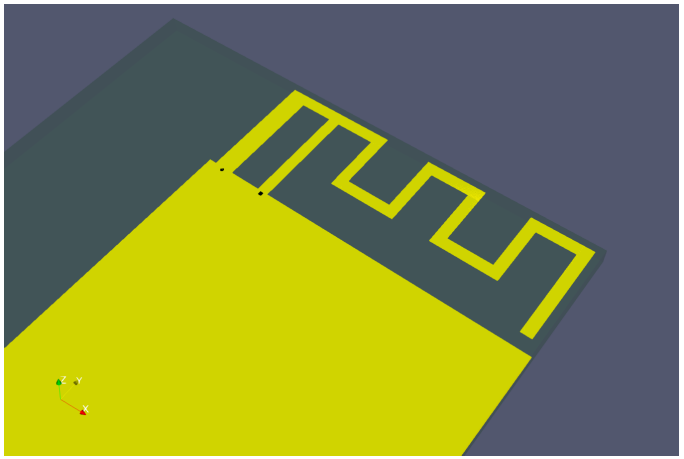
(a) $V_n = 1; \forall n = 1..6$

(b) $V_n = \exp(\mathrm{j}\, n\frac{2\pi}{N}); \forall n = 1..6$

Small Size Wifi PCB Antenna Example



(a) CC2511 USB Dongle [4]



(b) openEMS Model

Simulation Results:

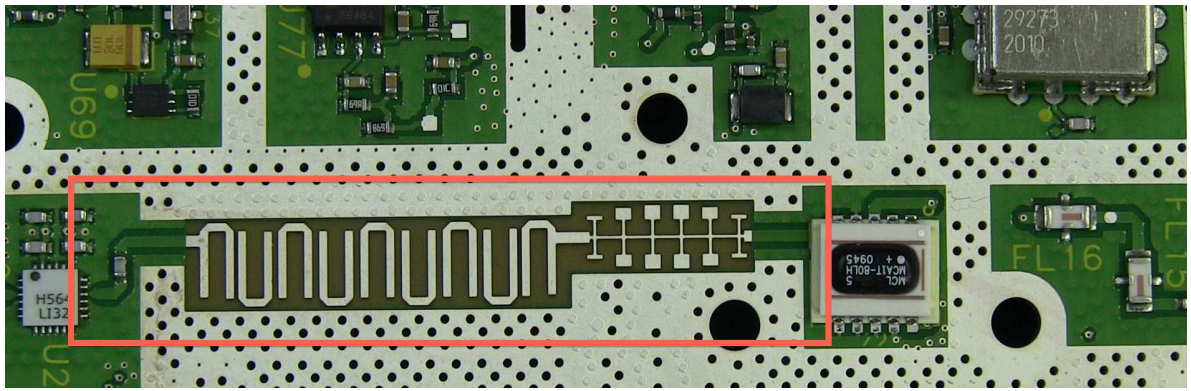
- Target frequency of $\approx 2.45\,\mathrm{GHz}$ is confirmed
- Antenna matching strongly depends on the PCB size
- RF simulation is important to adept to PCB size, material & thickness

[4] Source: `http://www.ti.com/lit/an/swra117d/swra117d.pdf`

Outline

Interfacing Tools - Why do we want them?

- Free & open source EM solver exists
- Free & open source PCB editors exists
- **Nice to have:** RF-Simulation of PCB
  - PCB trace antenna (wifi, bluetooth, NFC)
  - PCB trace filters and transmission lines (hairpin, notch, stub, ...)



[5]

- **But:** Weak open source link between both worlds ...
- Both worlds should be more connected & interfaced!?

[5] https://commons.wikimedia.org/wiki/File:Microstrip_Distributed_Element_Filter_Technology.jpg

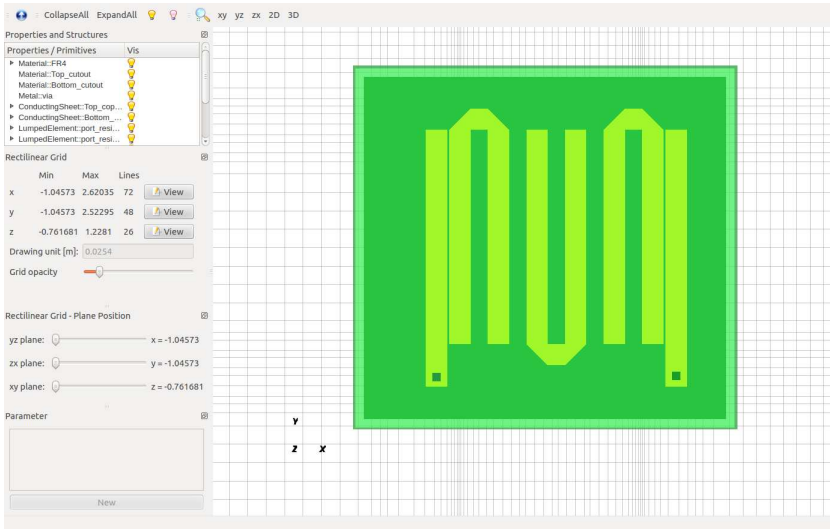
Interfacing Tools - Overview

There are some tools to interface with openEMS:

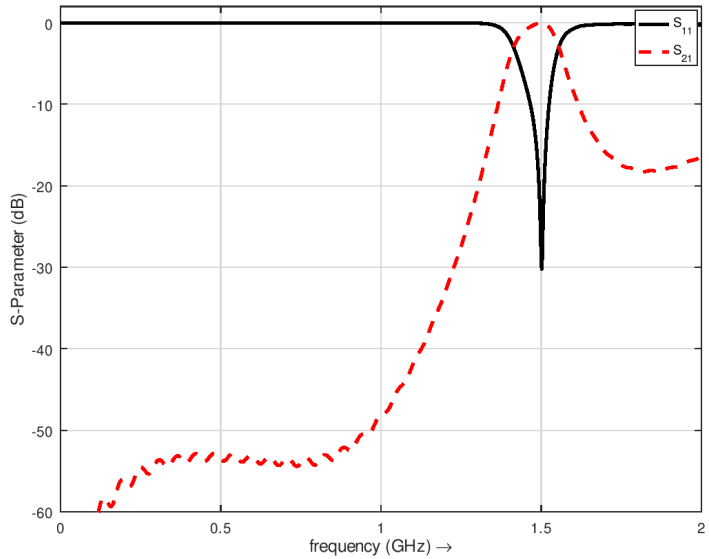
- hyp2mat
  - Reads commercial Hyperlynx format, writes openEMS solver script (Matlab/Octave)
  - Already included in openEMS package, including examples
  - `https://github.com/koendv/hyp2mat`
- pcb-rnd
  - Graphical, point and click PCB editor
  - Many import and export formats (kicad, eagle, protel, hyperlynx, hp-gl)
  - exporter to openEMS
  - `http://repo.hu/projects/pcb-rnd`
- pcbmodelgen
  - Convert KiCAD PCB files to models for import in openEMS
  - `https://github.com/jcyrax/pcbmodelgen`

Interfacing Tools - hyp2mat - Hairpin Filter Example

Hairpin filter imported from Eagle with hyp2mat:



(a) Model in openEMS

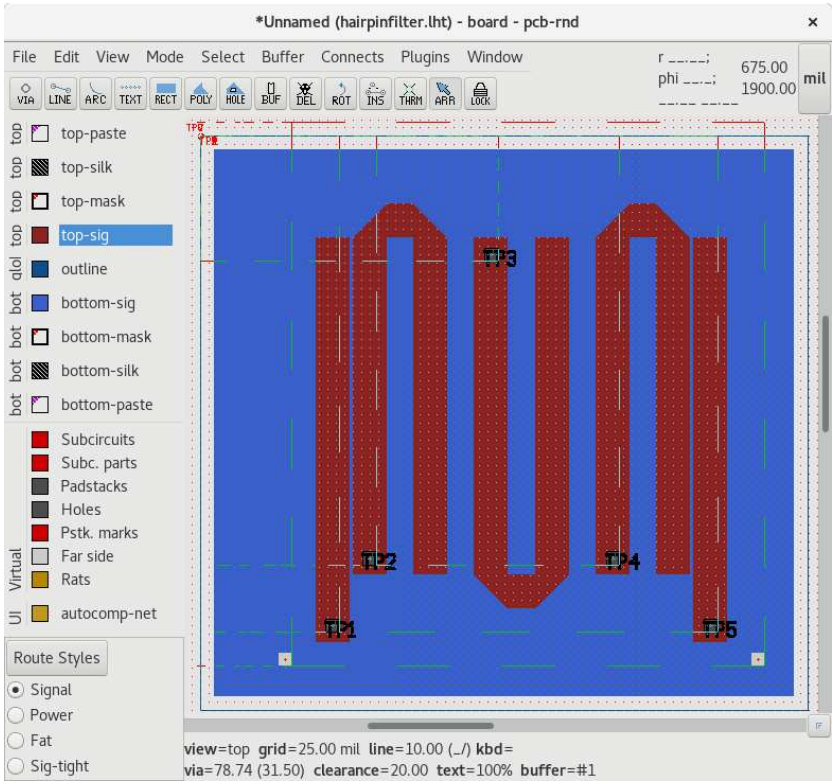


(b) S-Parameter Result from openEMS

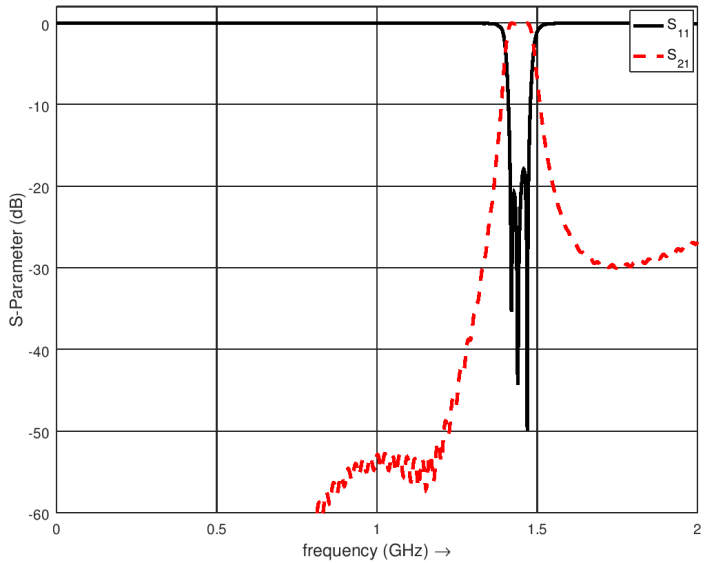
Source: Example included in hyp2mat

Interfacing Tools - pcb-rnd - Hairpin Filter Example

Hairpin filter from pcb-rnd:



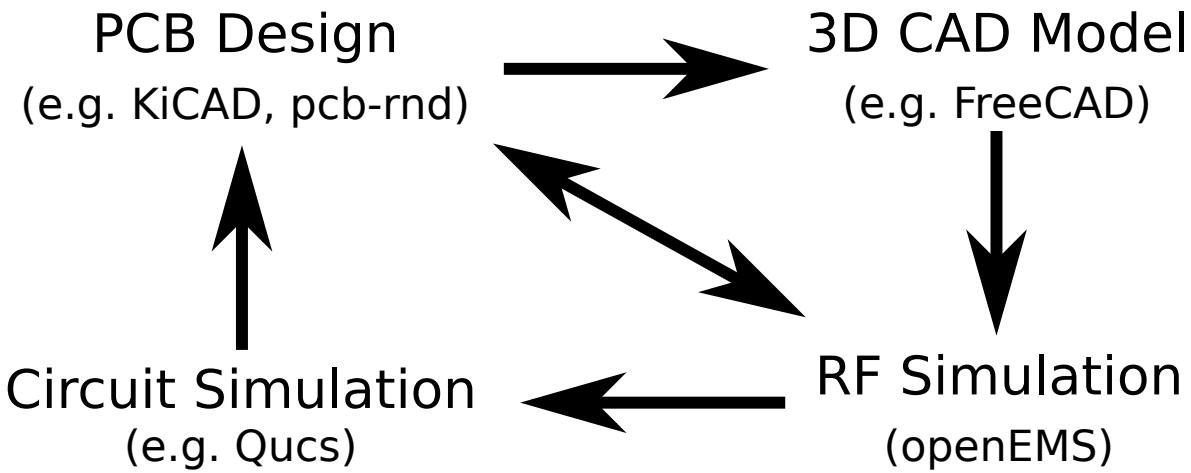
(a) Layout in pcb-rnd



(b) S-Parameter Result from openEMS

What would be the Ultimate Interfacing Goal?

1. Design your PCB with your favorite (free) PCB editor/designer
2. Design your 3D CAD models (e.g. housing, connector) with your favorite (free) CAD tool (e.g. FreeCad)
3. Import to openEMS and do your RF simulation
4. Import the touchstone results into your favorite (free) circuit simulation software (e.g. Qucs)



Outline

Status & Outlook

Project-Status:

- openEMS is a mature EM simulation package
- many (advanced) FDTD features already available

There is still a lot to do:

- Improve and expand the documentation
- Complete the python interface
- Continue efforts to interface with other EDA & CAD tools
- Add new FDTD features
- ...

Further Reading

For further information:	`www.ate.uni-due.de`
openEMS Website:	`http://openEMS.de`
openEMS Forum:	`http://openEMS.de/forum`
openEMS Development:	`https://github.com/thliebig`

openEMS is a free and open source software

$\Rightarrow$ **Feel free to download, evaluate and contribute**

Thank you for your attention!