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Introduction to antenna and near-field simulation in CST Microwave Studio® software

Jorge R. Costa
Jerzy Guterman

ISCTE
Instituto Superior de Ciências do Trabalho e da Empresa

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CST Design Environment

Analysis and design of static and low frequency EM applications

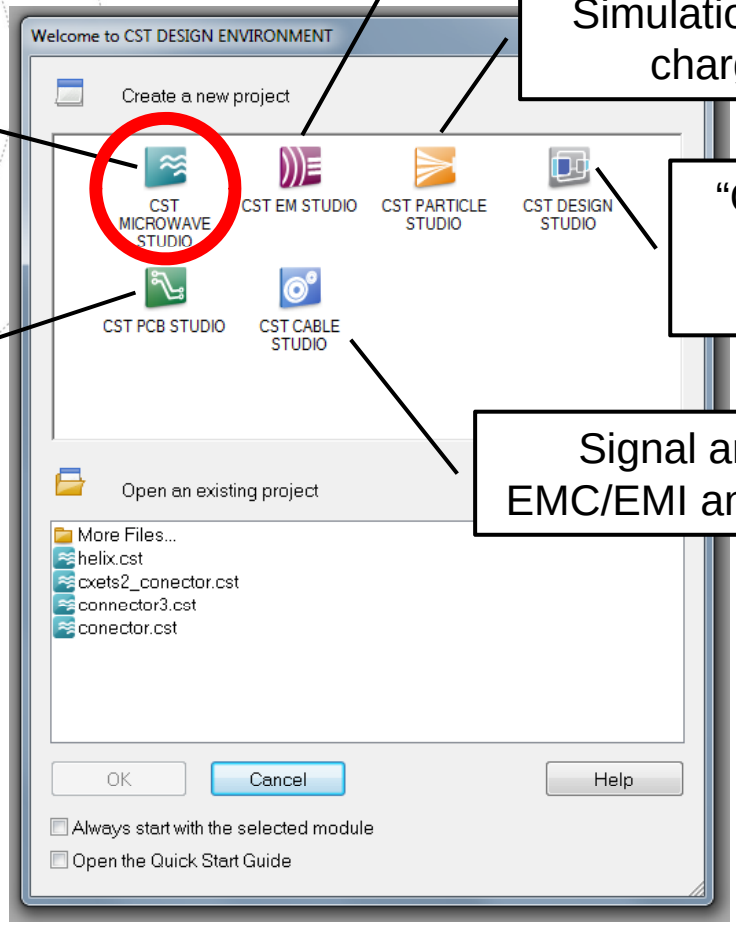
Simulation of free moving charged particles

3D EM simulation of high frequency problems

“Circuit tool” which combine results from other CST simulators

Signal and power integrity and EMC/EMI analysis on printed circuit boards

Signal and power integrity and EMC/EMI analysis of cable harnesses



CST MWS Simulation Method

FIT: Finite Integration Technique

Maxwell Equations

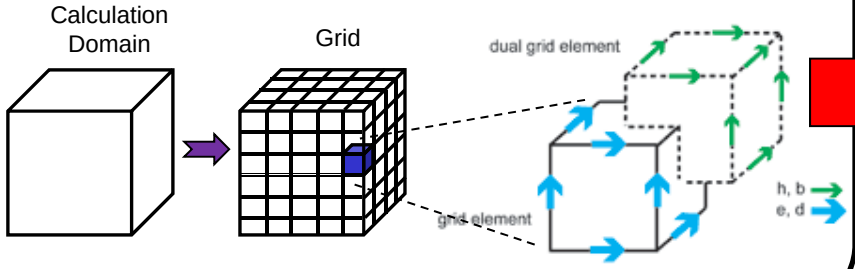
$$\oint_{\partial S} \vec{E} \cdot \vec{dl} = -\iint_{S} \frac{\partial \vec{B}}{\partial t} \cdot \vec{dS} \qquad \oint_{\partial S} \vec{H} \cdot \vec{dl} = \iint_{S} \left(\frac{\partial \vec{D}}{\partial t} + \vec{J} \right) \cdot \vec{dS}$$

$$\oiint_{\partial V} \vec{D} \cdot \vec{dS} = \iiint_{V} \rho \, dV \qquad \oiint_{\partial V} \vec{B} \cdot \vec{dS} = 0$$

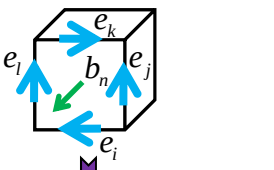
Maxwell Grid Equations

$$\mathbf{Ce} = -\frac{d}{dt}\mathbf{b} \qquad \tilde{\mathbf{C}}\mathbf{h} = \frac{d}{dt}\mathbf{d} + \mathbf{j}$$

$$\tilde{\mathbf{S}}\mathbf{d} = \mathbf{q} \qquad \mathbf{Sb} = 0$$



$$\oint_{\partial S} \vec{E} \cdot \vec{dl} = -\iint_{S} \frac{\partial \vec{B}}{\partial t} \cdot \vec{dS}$$



$$e_i + e_j - e_k - e_l = -\frac{d}{dt} b_n$$

$$\underbrace{\begin{bmatrix} 1 & 1 & -1 & -1 \end{bmatrix}}_{\mathbf{C}} \underbrace{\begin{bmatrix} e_i \\ e_j \\ e_k \\ e_l \end{bmatrix}}_{\mathbf{e}} = -\frac{d}{dt} \underbrace{\begin{bmatrix} b_n \end{bmatrix}}_{\mathbf{b}}$$

$$\mathbf{Ce} = -\frac{d}{dt}\mathbf{b}$$

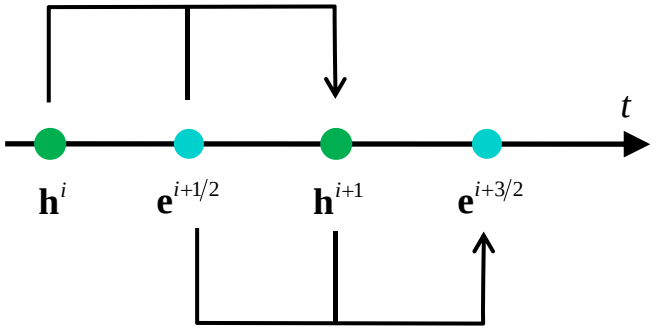
CST MWS Transient Solver

Material Equations

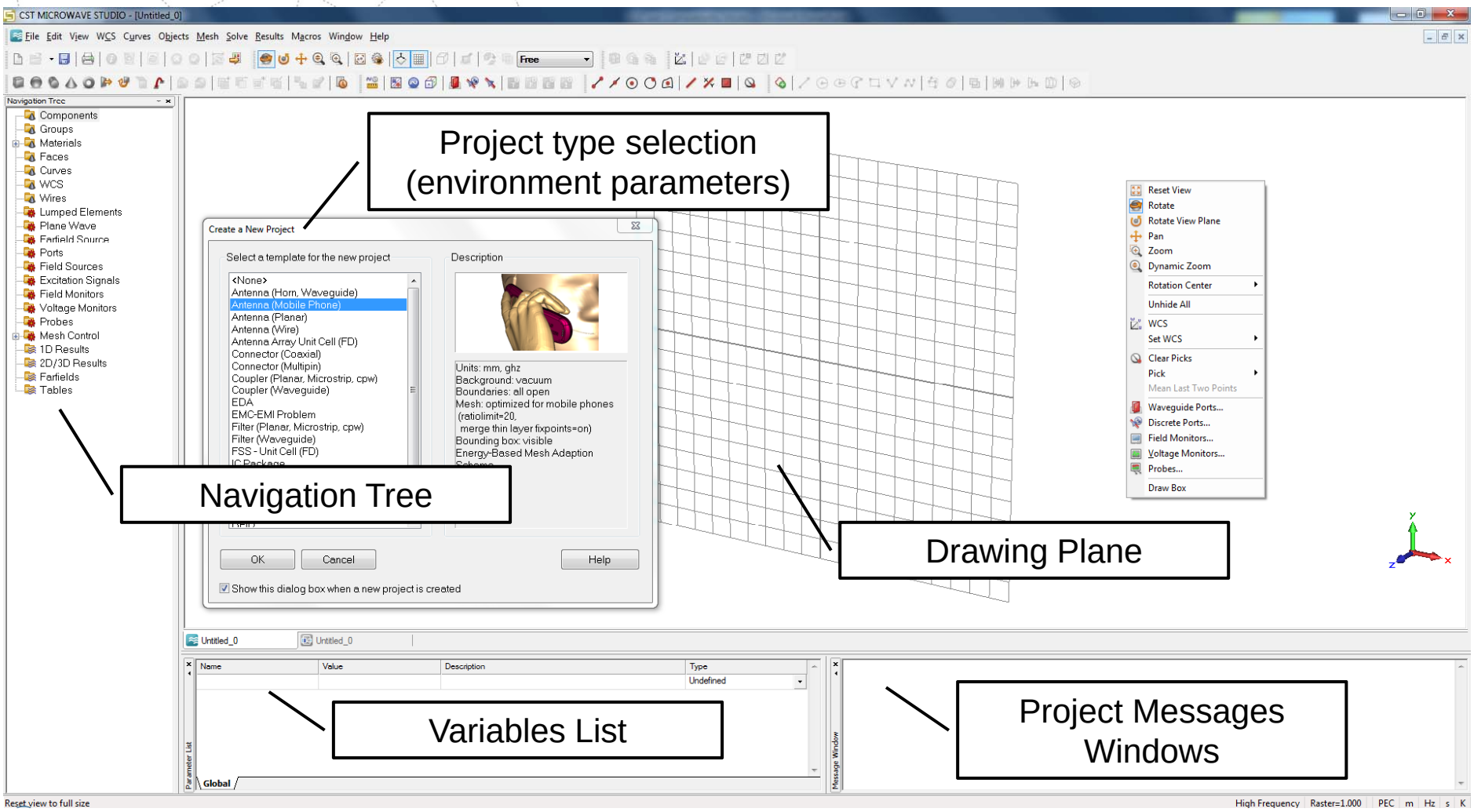
$$\vec{D} = \varepsilon \vec{E} \qquad \mathbf{d} = \mathbf{M}_\varepsilon \mathbf{e}$$
$$\vec{B} = \mu \vec{H} \Rightarrow \mathbf{b} = \mathbf{M}_\mu \mathbf{h}$$
$$\vec{J} = \sigma \vec{E} + \vec{J_s} \qquad \mathbf{j} = \mathbf{M}_\sigma \mathbf{e} + \mathbf{j}_s$$

Transient Solver

$$\mathbf{h}^{i+1} = \mathbf{h}^{i} - \Delta t \, \mathbf{M}_\mu^{-1} \mathbf{C} \mathbf{e}^{i+1/2}$$
$$\mathbf{e}^{i+3/2} = \mathbf{e}^{i+1/2} + \Delta t \, \mathbf{M}_\varepsilon^{-1} \left[\tilde{\mathbf{C}} \mathbf{h}^{i+1} - \mathbf{j}^{i+1} \right]$$



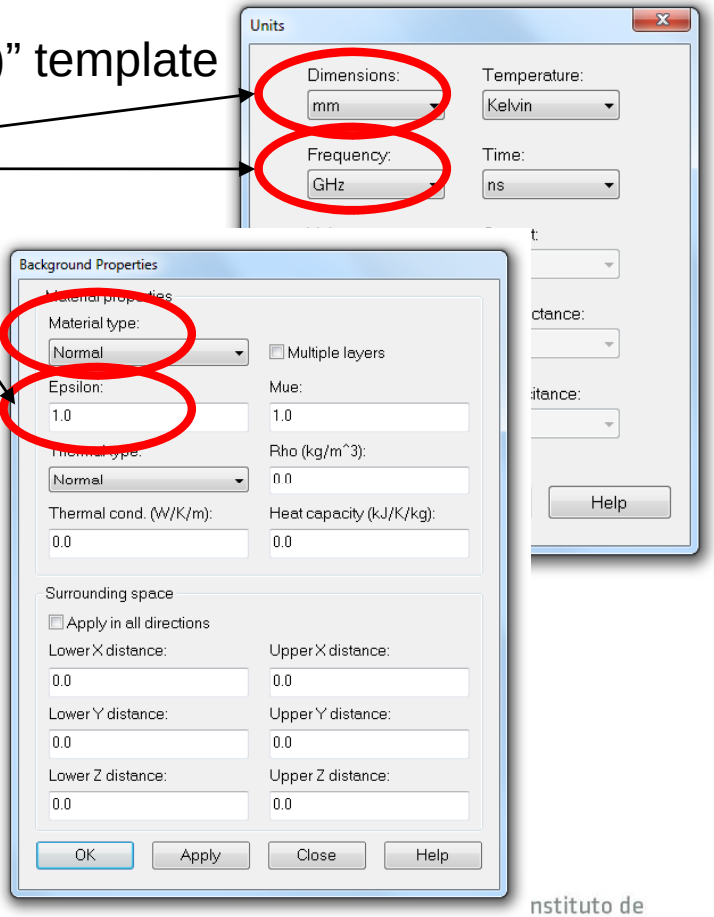
CST MWS User Interface



1st Example: Dipole Antenna

Initial Setup

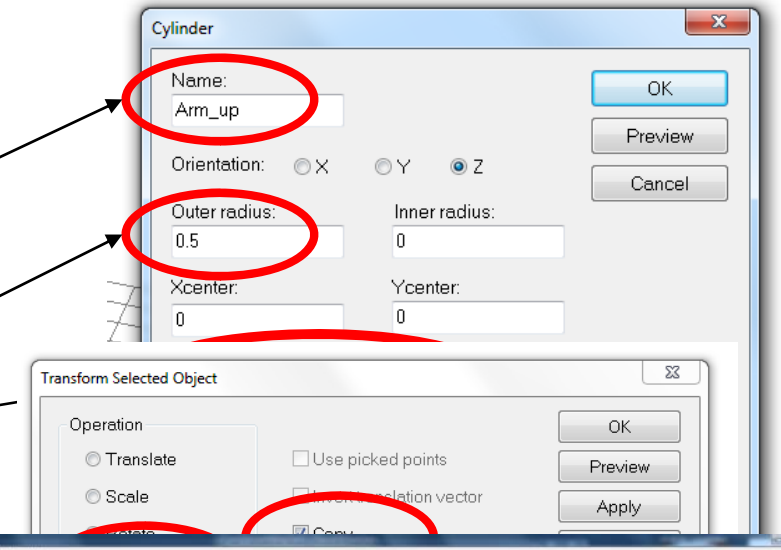
- Select new project in CST MWS
- Select “Antenna (Mobile Phone)” template
- Confirm units
- Confirm environment (air)

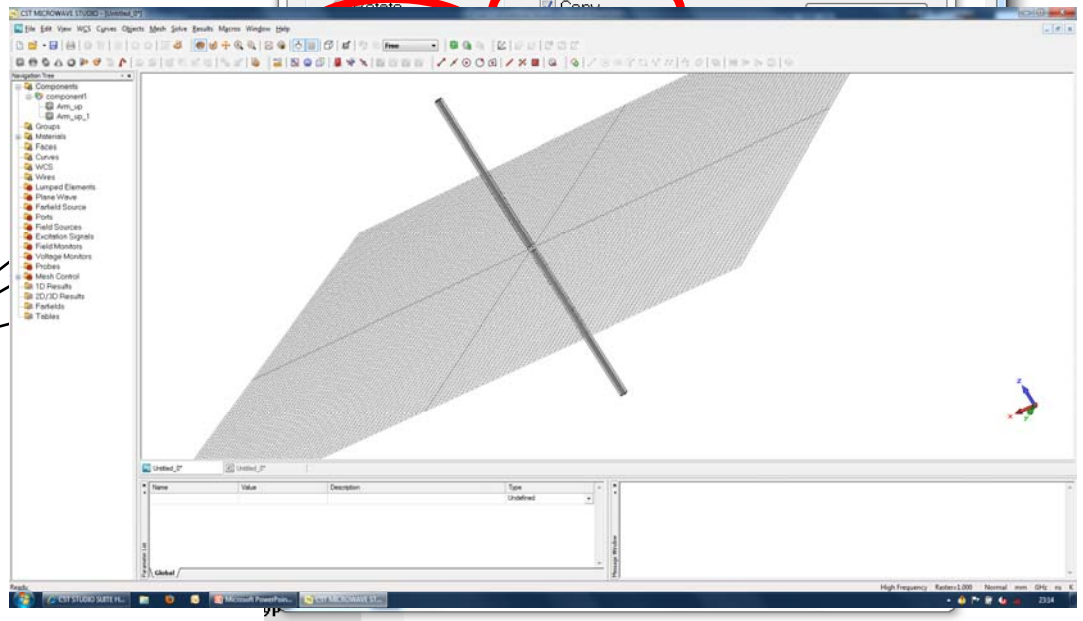


1st Example: Dipole Antenna

Geometry Drawing

- Draw cylinder
- Name: “Arm_up”
- Dimensions (in mm)
- Material: Perfect Electric Conductor – “PEC”
- Select object in navigation tree
- Object transform



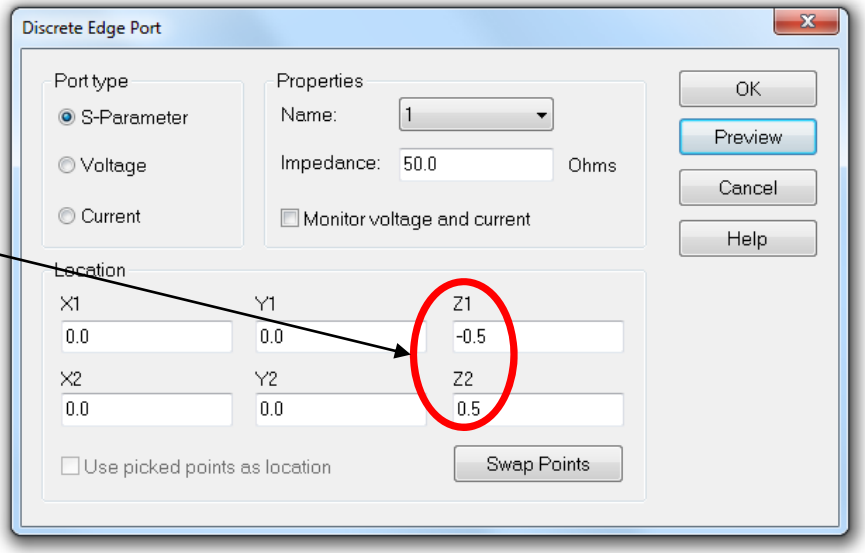


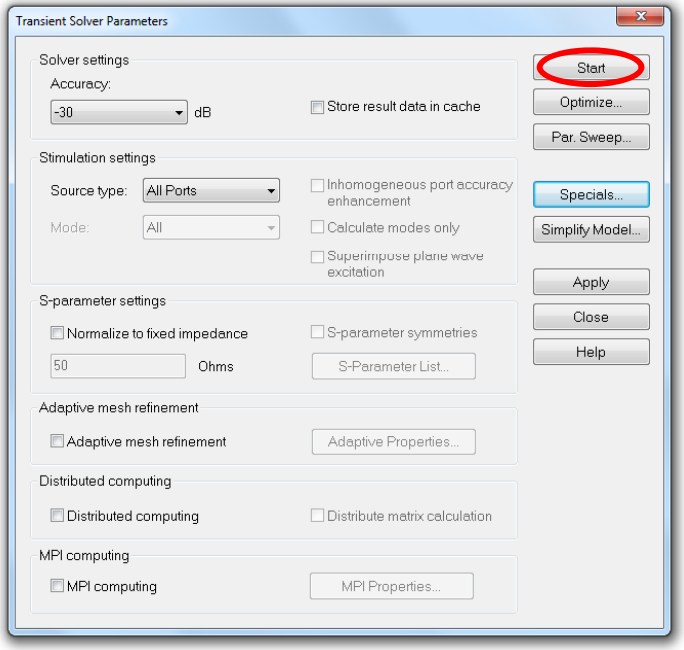
herm.cond. PTC

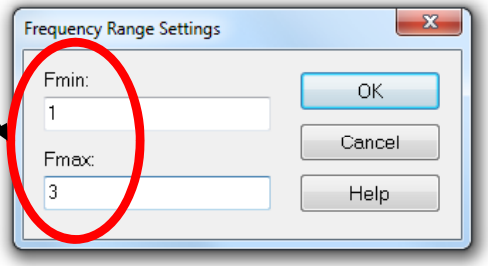
1st Example: Dipole Antenna

Excitation and Simulation Setup

- Insert discrete port
- Setup frequency range
- Run Transient Solver



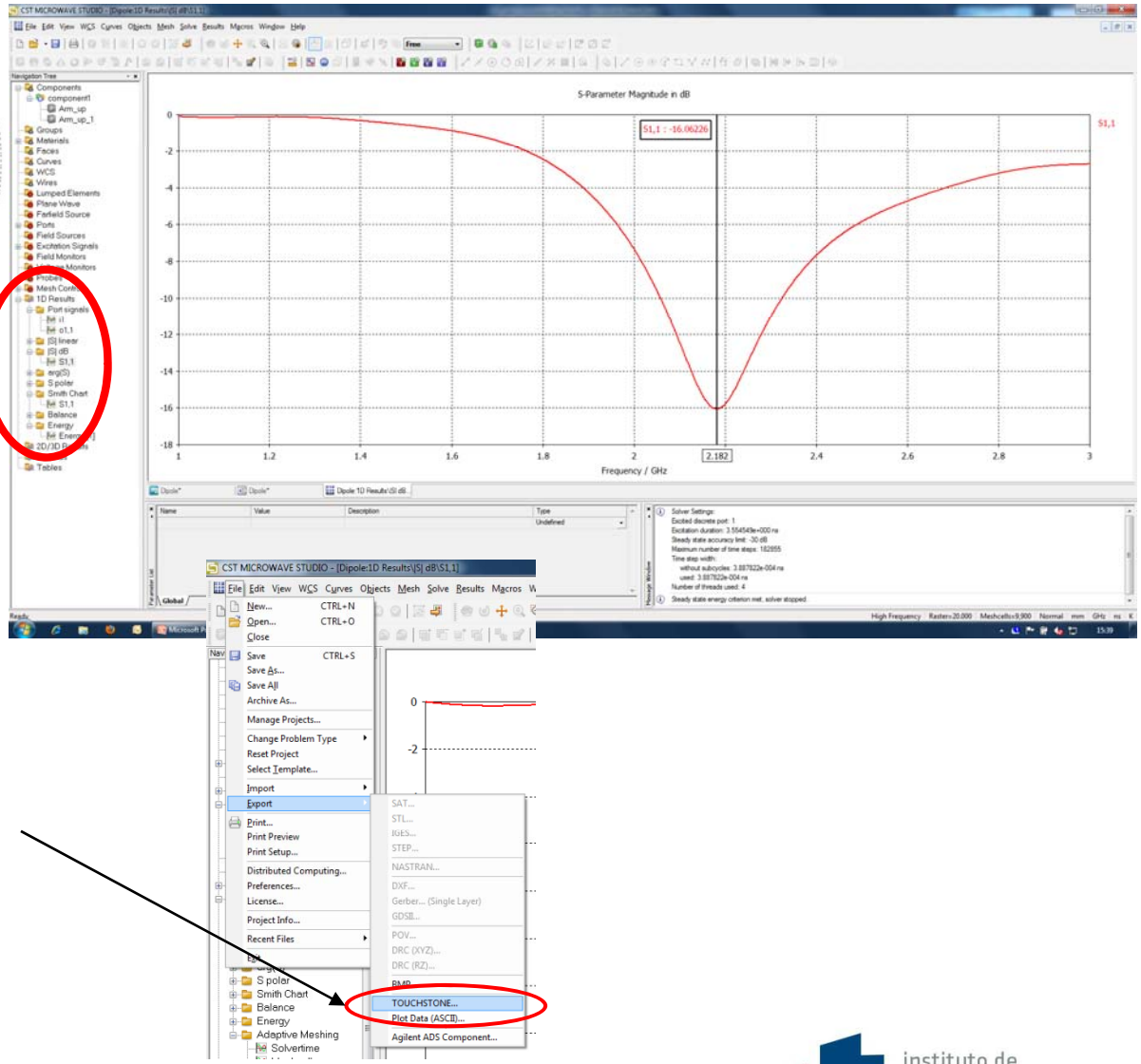




1st Example: Dipole Antenna

1D Results

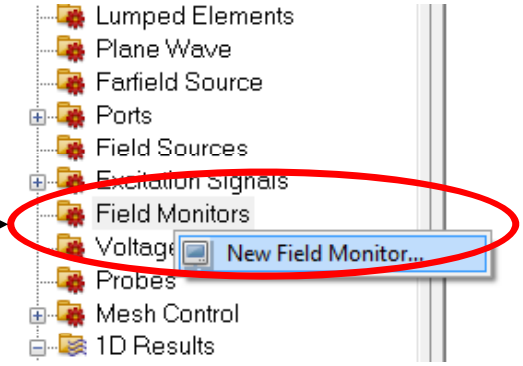
- In navigation tree go to 1D Results
  - S_{11}
  - Smith Chart
  - Port Signal
  - Energy
- Can export results in txt file or TOUCHSTONE format

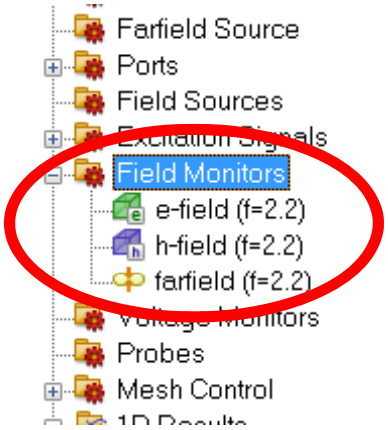


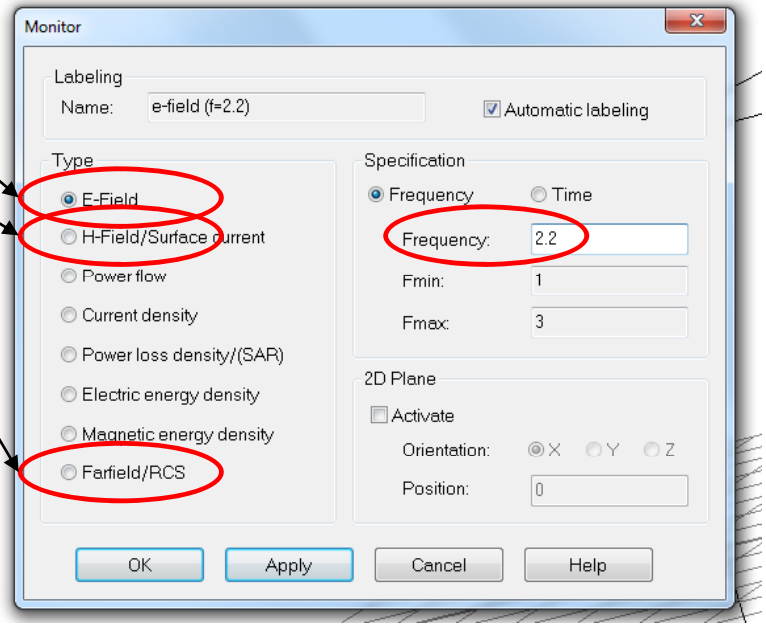
1st Example: Dipole Antenna

Setting Monitors

- Add Field Monitors (navigation tree + right mouse bottom):
  - E-field @ 2.2 GHz
  - H-field @ 2.2 GHz
  - Farfield/RCS @ 2.2 GHz



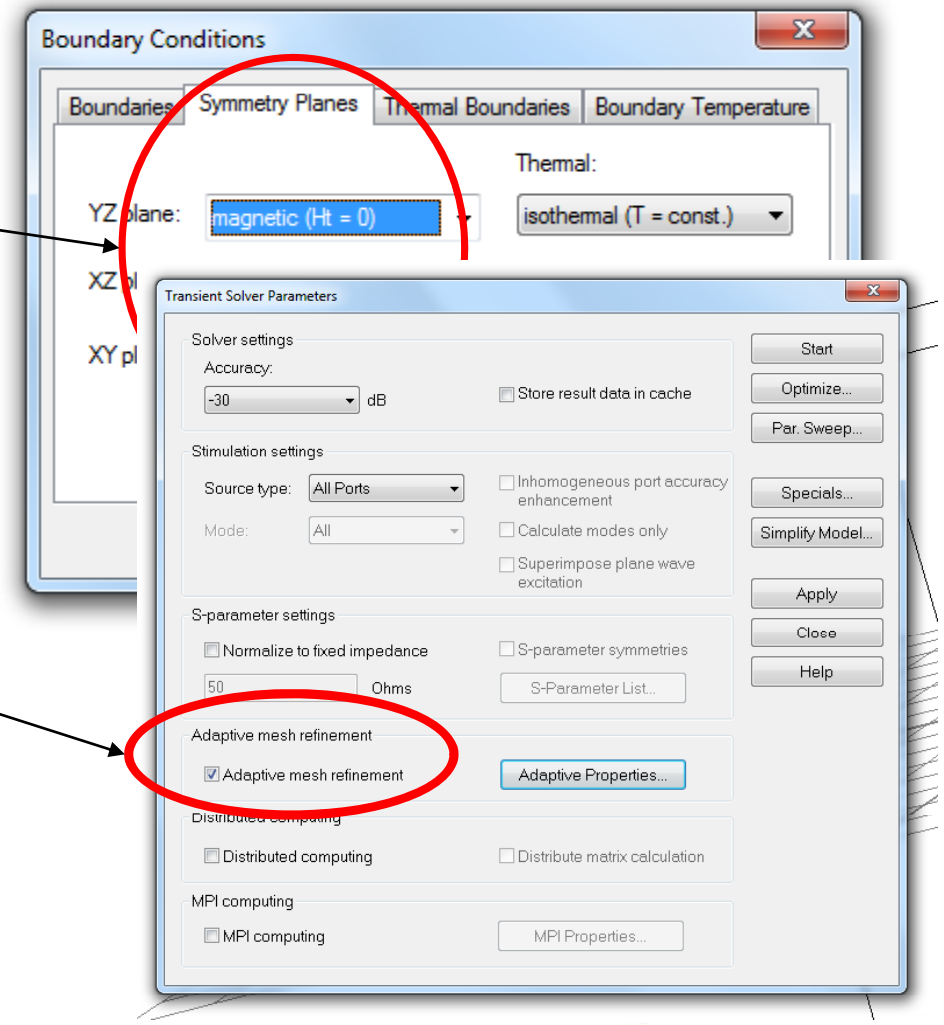




1st Example: Dipole Antenna

Improving simulation

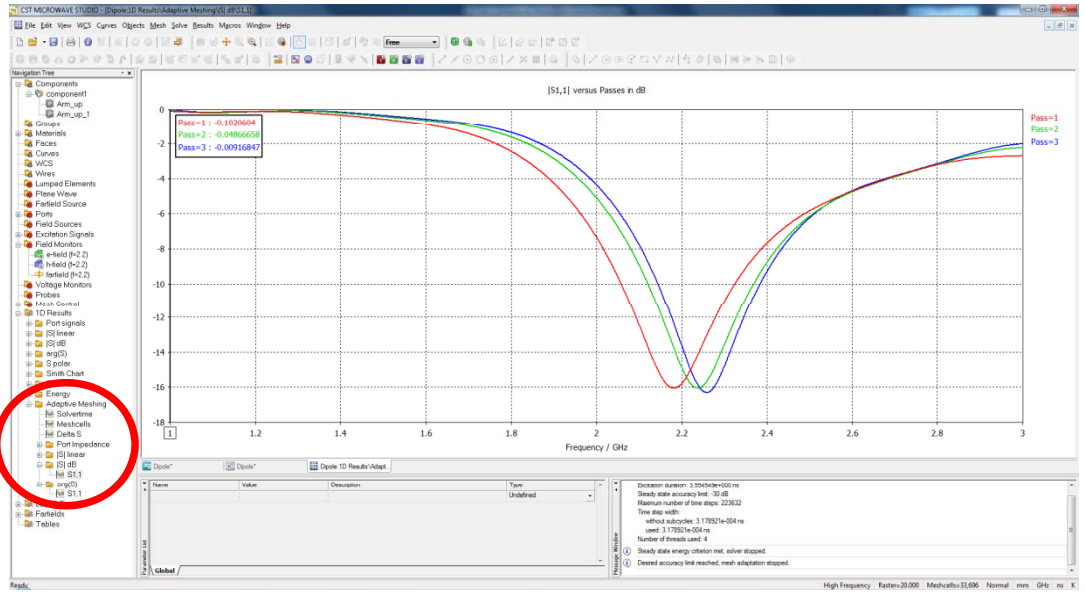
- Boundary Conditions -> Symmetry Planes
  - YZ plane: magnetic (Ht=0)
  - XZ plane: magnetic (Ht=0)
  - XY plane: electric (Et=0)
- Transient Solver
  - Adaptive mesh refinement



1st Example: Dipole Antenna

Adaptive mesh results

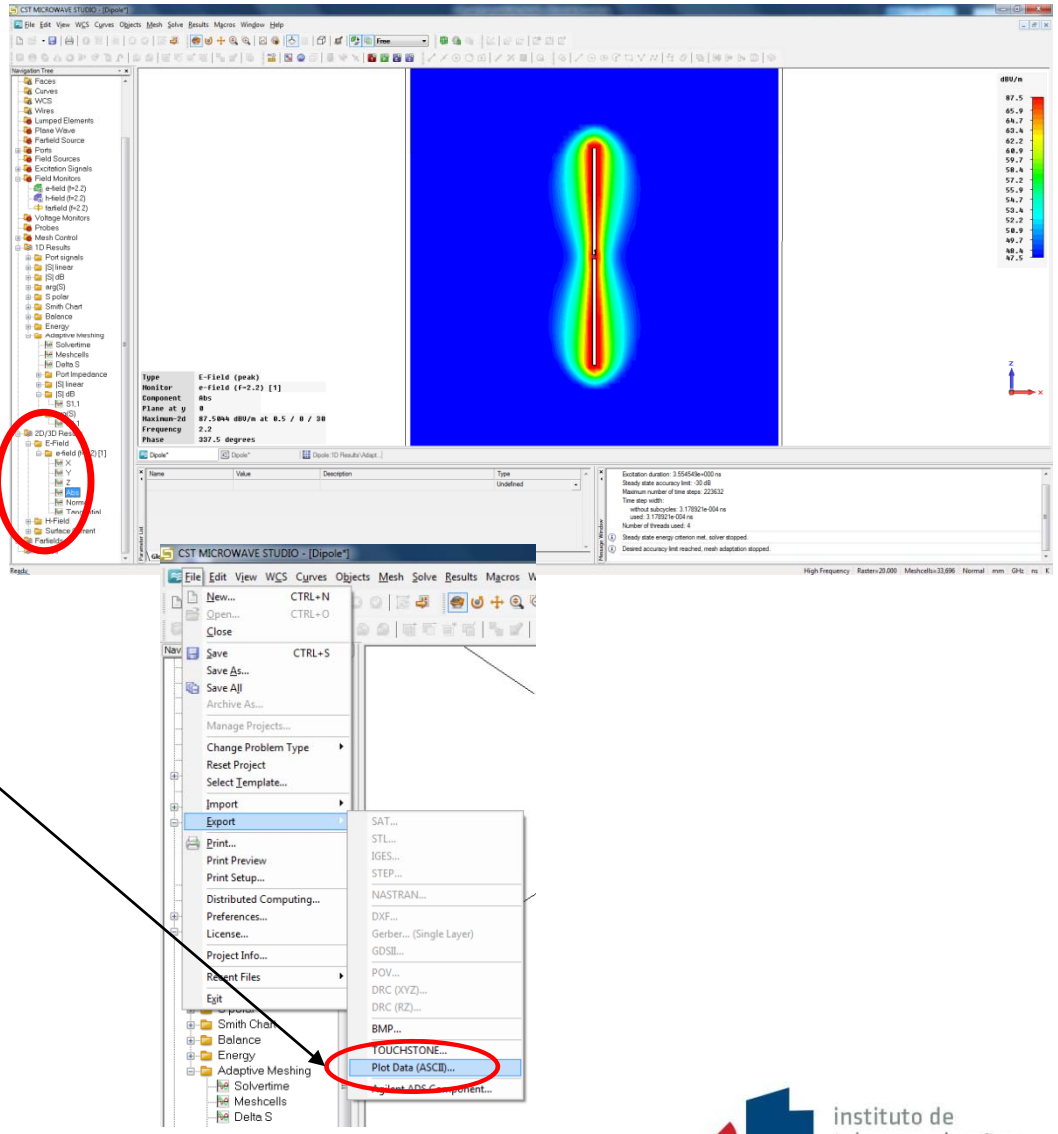
- In navigation tree go to 1D Results -> Adaptive Meshing
  - S_{11}
  - Mesh cells
  - Solver time
- Transient Solver
  - Deselect “Adaptive mesh refinement”
  - Press Apply



1st Example: Dipole Antenna

Near-field results

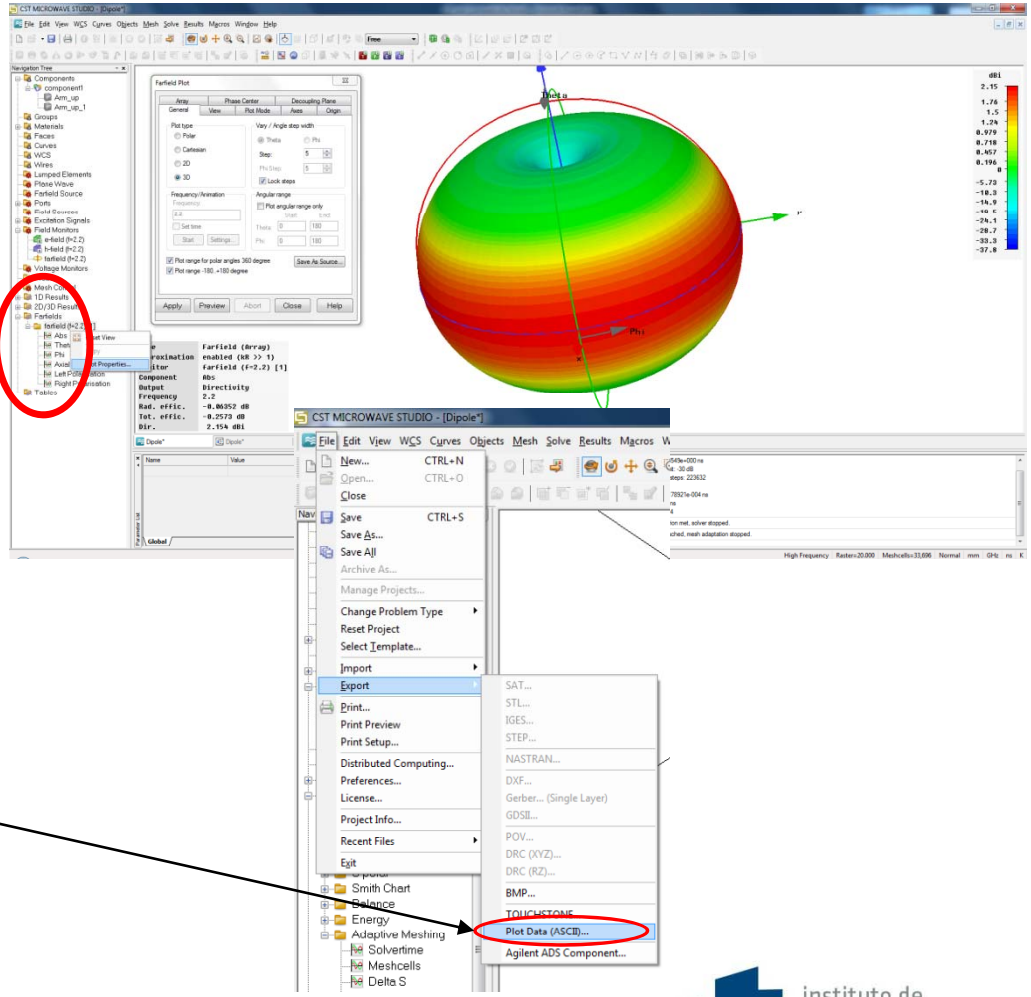
- In navigation tree go to 2D/ 3D Results -> E-field or H-field:
  - Field components
  - Amplitudes
  - Phases
- Can export results in txt file



1st Example: Dipole Antenna

Far-field results

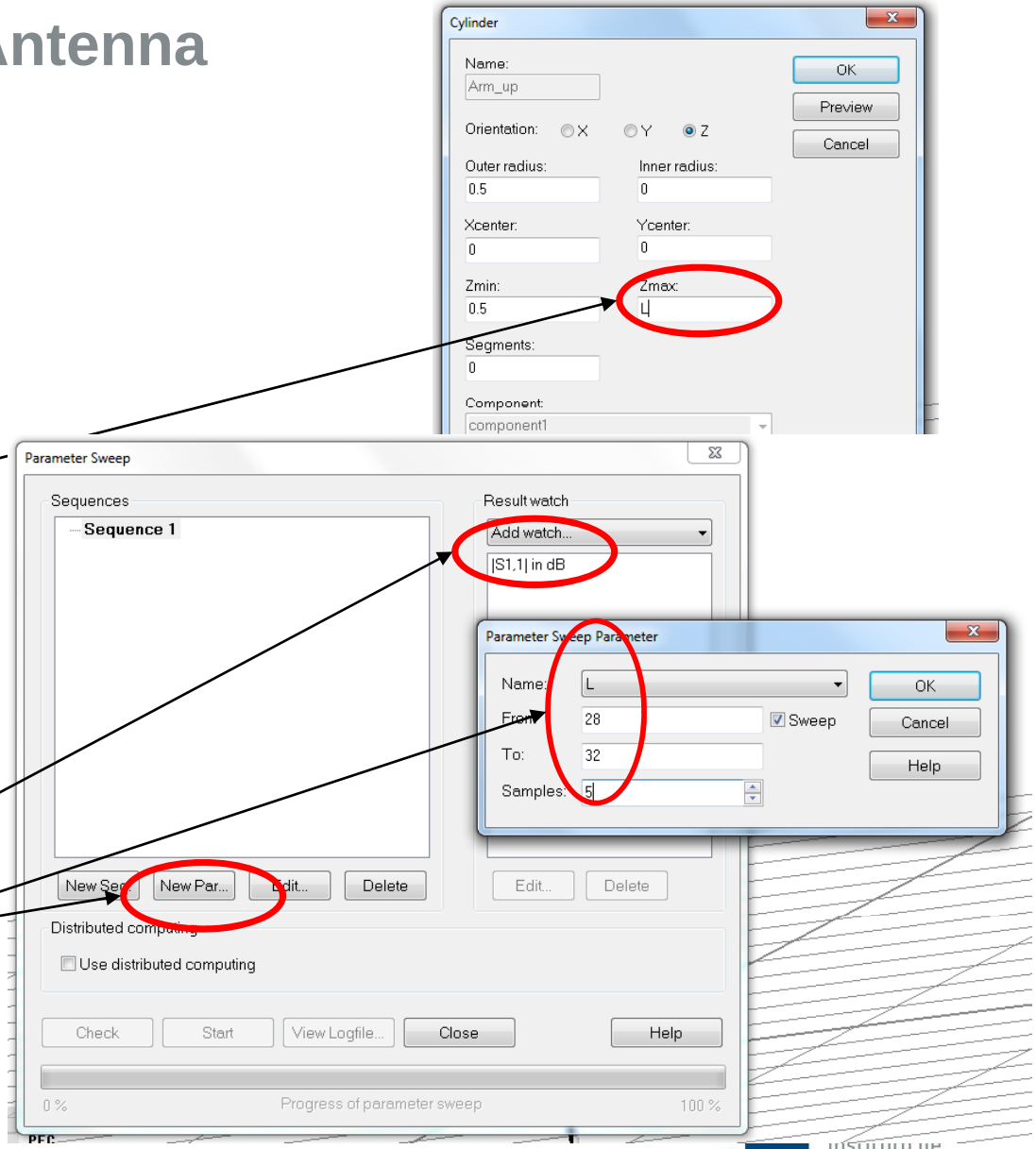
- In navigation tree go to Farfields:
  - Field components
  - Co-pol. and Cross-pol.
  - Polar, 2D or 3D
  - Rad. Efficiency
  - Directivity or Gain
- Can export results in txt file or in GRASP format



1st Example: Dipole Antenna

Structure Parameterization

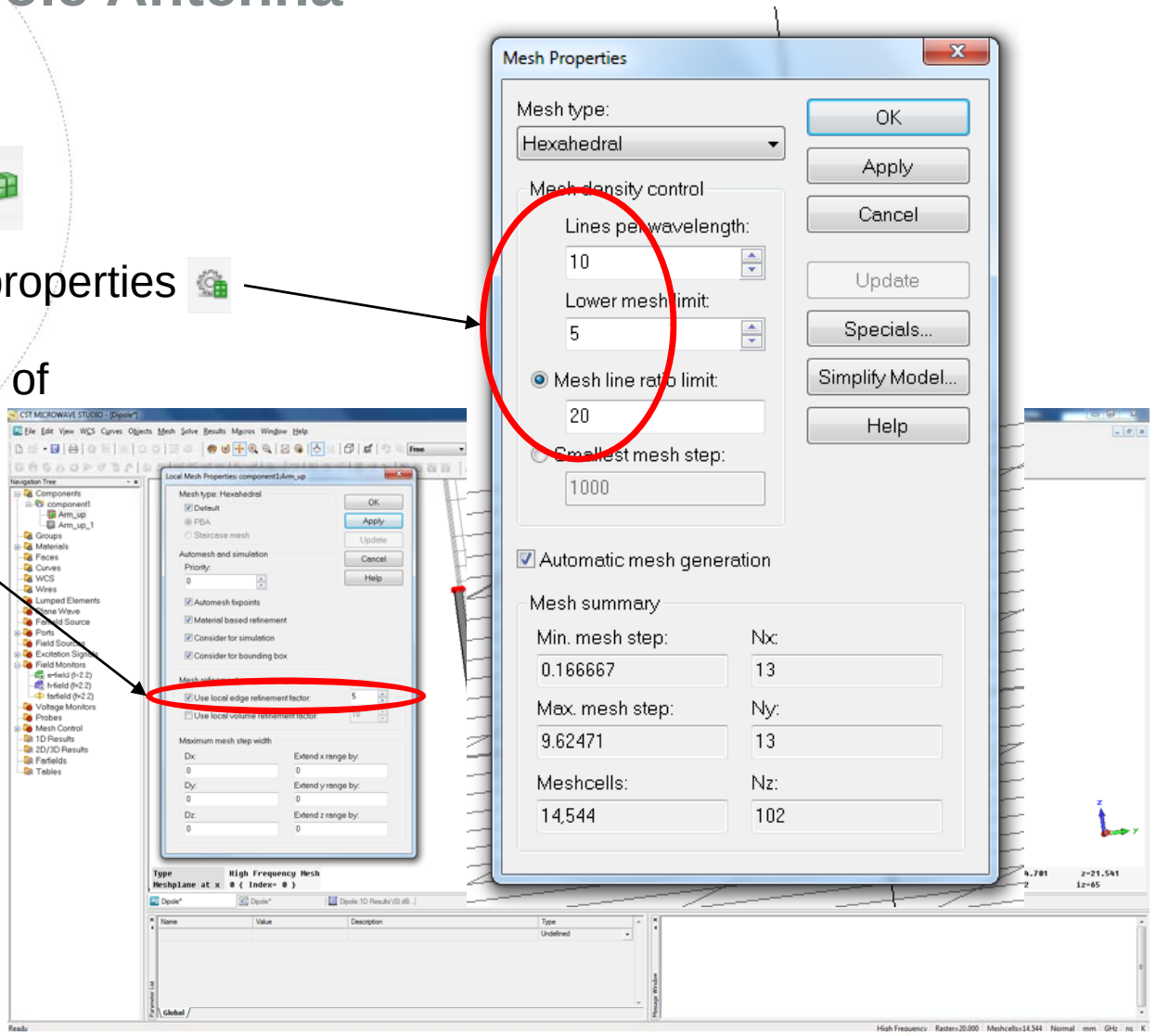
- Select “Arm_up” in navigation tree
- Edit object
- In define cylinder, change Zmax to variable “L”
- Transient Solver
  - Par. Sweep
  - Add watch S_{11} in dB
  - New Seq. & New Par. “L”
- Check & Start



1st Example: Dipole Antenna

Mesh Operations

- Enable mesh view
- View global mesh properties
- Change local mesh of "Arm_up"



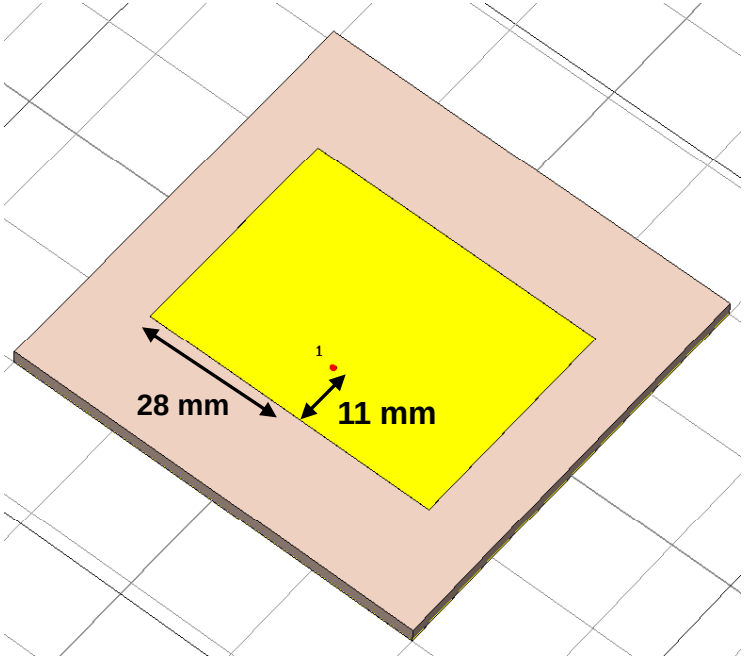
Visit CST Website

www.cst.com

2nd Example: Microstrip Patch

Geometry Drawing

- New Project
- Draw “Ground”, “Substrate” and “Patch”
- Define discrete port
  (use local coordinate system)
- Setup frequency range (1 to 3 GHz)
  & Field Monitors @ 2.2 GHz
- Run transient solver

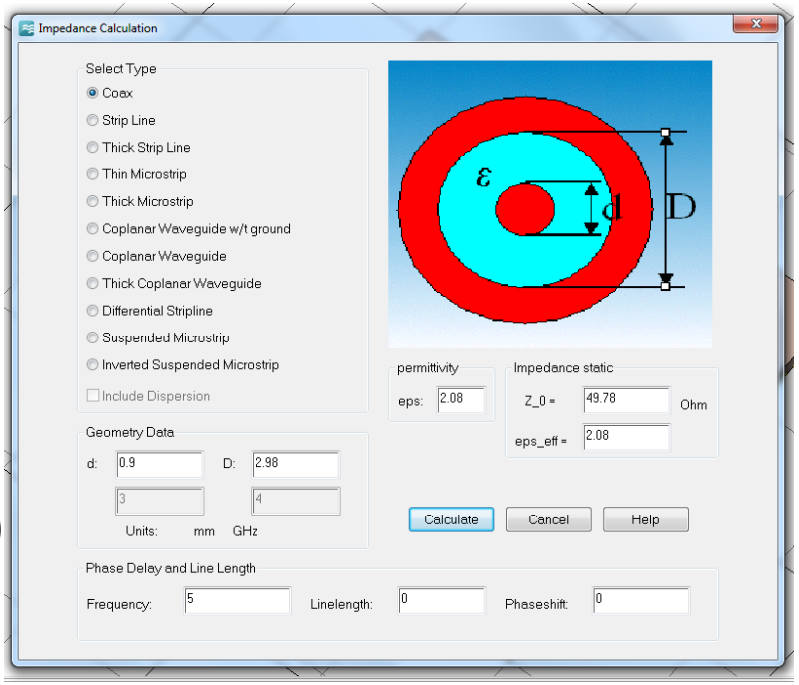


Object	Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	Material
Ground	-40	40	-40	40	0	0.02	Copper
Substrate	-40	40	-40	40	0.02	3	RT5880
Patch	-28	28	-21	21	3	3.02	Copper

2nd Example: Microstrip Patch

Coaxial Feed (Part 1)

- Copy S_{11} dB curve & delete discrete port
- Macros -> Calculate -> Analytical Line Impedance
- Draw “Inner Conductor” cylinder:
  - Select “Ground” (repeat for “Substrate”)
  - Object -> Boolean -> Insert -> “Inner Conductor”

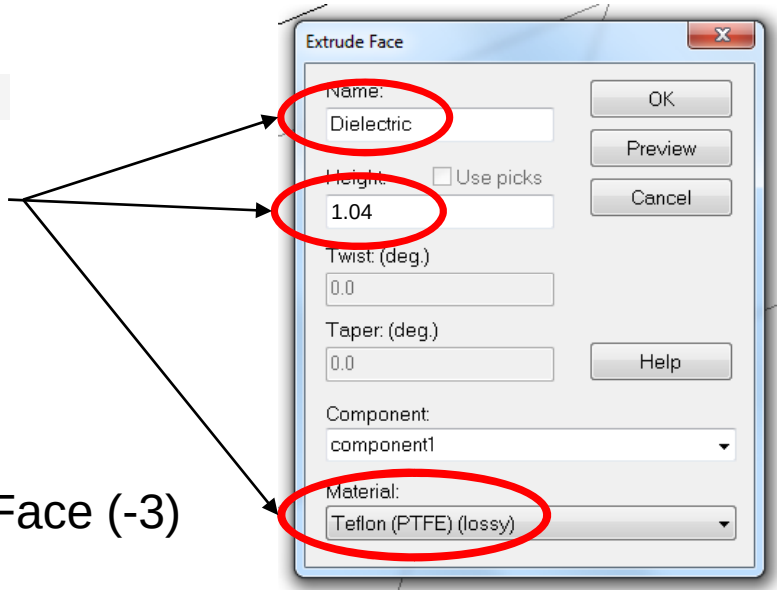


Object	Radius	Zmin	Zmax	Material
Inner Conductor	0.45	-20	3	Copper
Dielectric	1.49	-20	0	Teflon (ε_r = 2.08)
Outer Conductor	1.8	-20	0	Copper

2nd Example: Microstrip Patch

Coaxial Feed (Part 2)

- Pick lateral face of “Inner Conductor”
- Object -> Extrude -> create “Dielectric”
- Repeat for “Outer Conductor”
- Pick top face of “Dielectric”
- Object -> Local Modifications -> Move Face (-3)
- Repeat for “Outer Conductor”

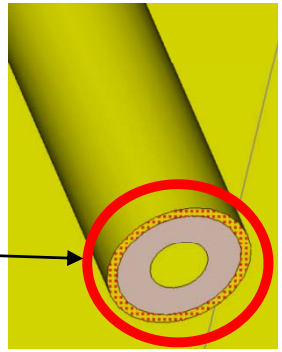


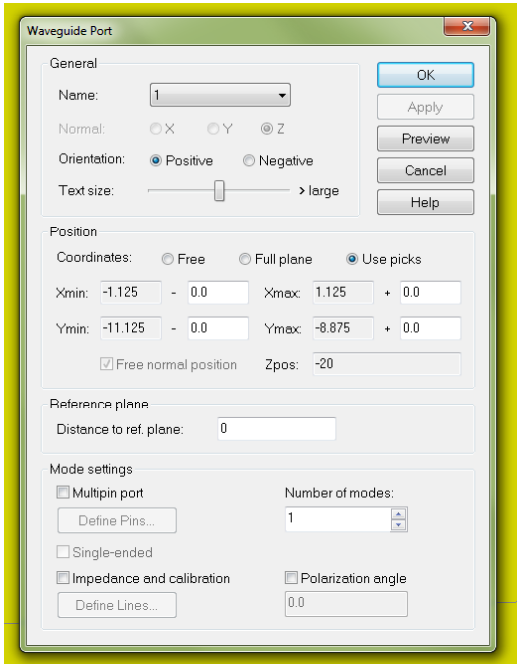
Object	Radius	Zmin	Zmax	Material
Inner Conductor	0.45	-20	3	Copper
Dielectric	1.49	-20	0	Teflon (ε_r = 2.08)
Outer Conductor	1.8	-20	0	Copper

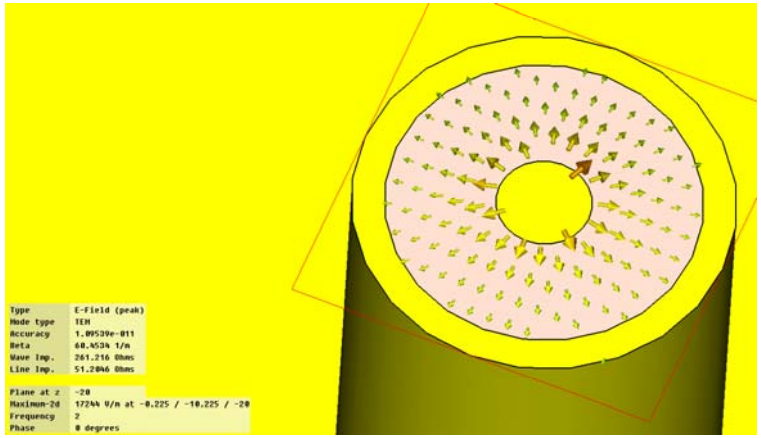
2nd Example: Microstrip Patch

Waveguide Port

- Pick bottom face of “Outer Conductor”
- Select Waveguide Port
- Run Transient Solver
- In navigation tree see 2D/3D Results -> Port Modes
- Compare S_{11} curves



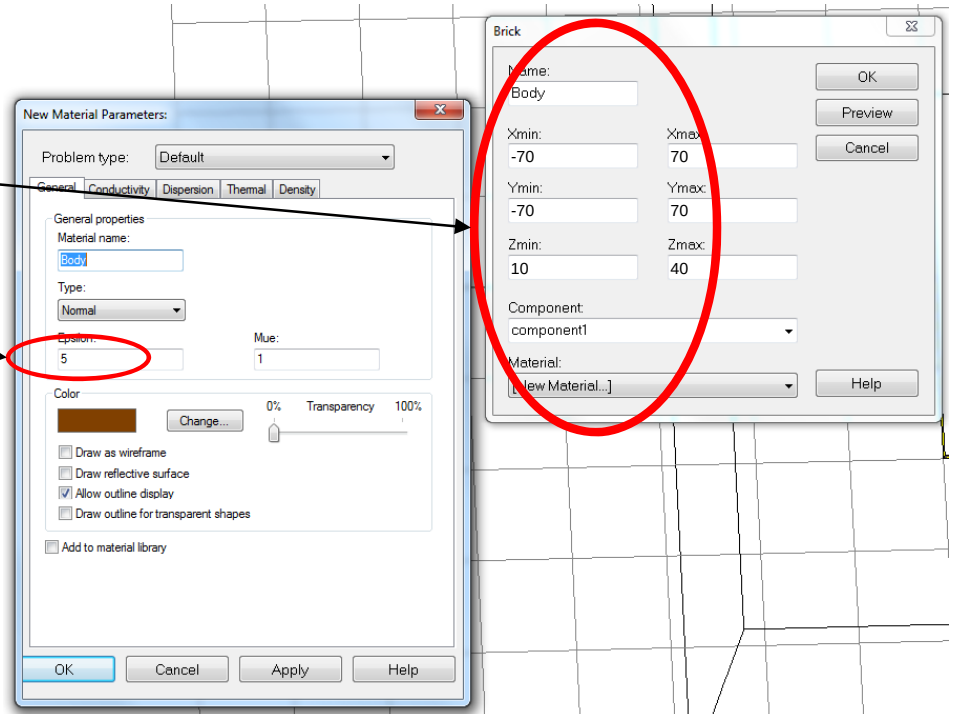




2nd Example: Microstrip Patch

Simulation of a body above antenna

- Copy E- and H-planes radiation patterns
- Copy S_{11} dB curve
- Create brick of "Body":
  - Create new material "Body" ε_r=5 and σ=1 (S/m)
- Run Transient Solver
- See S_{11} curve & radiation patterns



Questions ?

After a CST simulation ...