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Lisbon, IT, 22 March 2010

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

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Inovação



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# CST Design Environment

3D EM simulation of high frequency problems

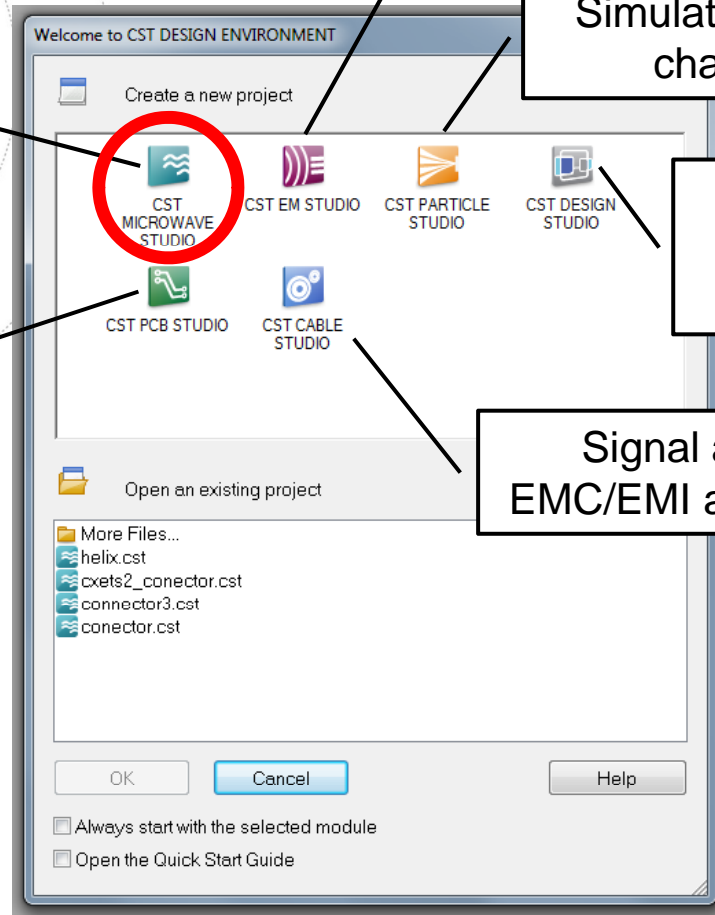
Signal and power integrity and EMC/EMI analysis on printed circuit boards

Analysis and design of static and low frequency EM applications

Simulation of free moving charged particles

“Circuit tool” which combine results from other CST simulators

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



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# CST MWS Simulation Method

*FIT: Finite Integration Technique*

## Maxwell Equations

$$\oint_{\partial S} \vec{E} \cdot d\vec{l} = - \iint_S \frac{\partial \vec{B}}{\partial t} \cdot d\vec{S} \quad \oint_{\partial S} \vec{H} \cdot d\vec{l} = \iint_S \left( \frac{\partial \vec{D}}{\partial t} + \vec{J} \right) \cdot d\vec{S}$$

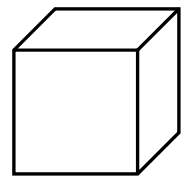
$$\iiint_{\partial V} \vec{D} \cdot d\vec{S} = \iiint_V \rho dV \quad \iiint_{\partial V} \vec{B} \cdot d\vec{S} = 0$$

## Maxwell Grid Equations

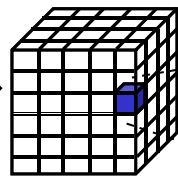
$$\mathbf{C}\mathbf{e} = -\frac{d}{dt}\mathbf{b} \quad \tilde{\mathbf{C}}\mathbf{h} = \frac{d}{dt}\mathbf{d} + \mathbf{j}$$

$$\tilde{\mathbf{S}}\mathbf{d} = \mathbf{q} \quad \mathbf{S}\mathbf{b} = 0$$

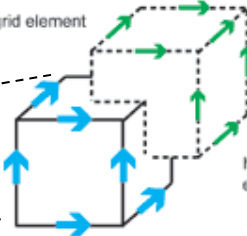
Calculation Domain



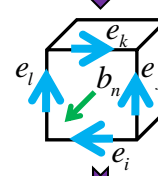
Grid



dual grid element



$$\oint_{\partial S} \vec{E} \cdot d\vec{l} = - \iint_S \frac{\partial \vec{B}}{\partial t} \cdot d\vec{S}$$



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

$$\mathbf{C}\mathbf{e} = -\frac{d}{dt}\mathbf{b}$$

$$\begin{bmatrix} 1 & 1 & -1 & -1 \end{bmatrix} \begin{bmatrix} e_i \\ e_j \\ e_k \\ e_l \end{bmatrix} = -\frac{d}{dt} \begin{bmatrix} b_n \end{bmatrix}$$

$$\mathbf{C} \mathbf{e} = -\frac{d}{dt} \mathbf{b}$$

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# CST MWS Transient Solver

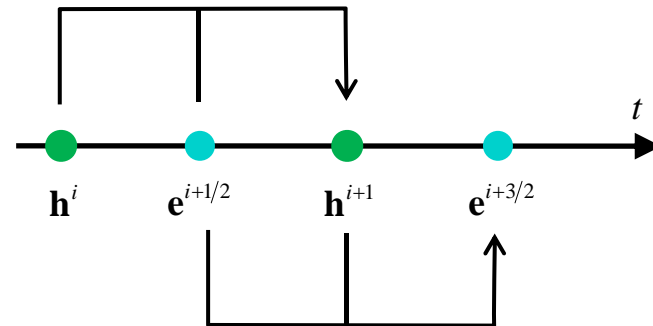


## Material Equations

$$\begin{aligned}
 \vec{D} &= \epsilon \vec{E} & \mathbf{d} &= \mathbf{M}_\epsilon \mathbf{e} \\
 \vec{B} &= \mu \vec{H} & \mathbf{b} &= \mathbf{M}_\mu \mathbf{h} \\
 \vec{J} &= \sigma \vec{E} + \vec{J}_s & \mathbf{j} &= \mathbf{M}_\sigma \mathbf{e} + \mathbf{j}_s
 \end{aligned}
 \quad \rightarrow$$

## Transient Solver

$$\begin{aligned}
 \mathbf{h}^{i+1} &= \mathbf{h}^i - \Delta t \mathbf{M}_\mu^{-1} \mathbf{C} \mathbf{e}^{i+1/2} \\
 \mathbf{e}^{i+3/2} &= \mathbf{e}^{i+1/2} + \Delta t \mathbf{M}_\epsilon^{-1} [\tilde{\mathbf{C}} \mathbf{h}^{i+1} - \mathbf{j}^{i+1}]
 \end{aligned}$$



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# CST MWS User Interface



The screenshot shows the CST MICROWAVE STUDIO interface. A 'Create a New Project' dialog box is open, displaying a list of project templates. The 'Antenna (Mobile Phone)' template is selected. A callout box points to this dialog with the text 'Project type selection (environment parameters)'. On the left, the 'Navigation Tree' is visible, listing various components like Materials, Curves, and Wires. A callout box points to it with the text 'Navigation Tree'. In the center, a 3D grid representing a 'Drawing Plane' is shown. A callout box points to it with the text 'Drawing Plane'. At the bottom, there is a 'Variables List' window and a 'Project Messages Windows' window. Callout boxes point to these windows with the text 'Variables List' and 'Project Messages Windows' respectively. The software's menu bar and toolbar are visible at the top.

Reset view to full size

High Frequency Raster=1.000 PEC m Hz s K

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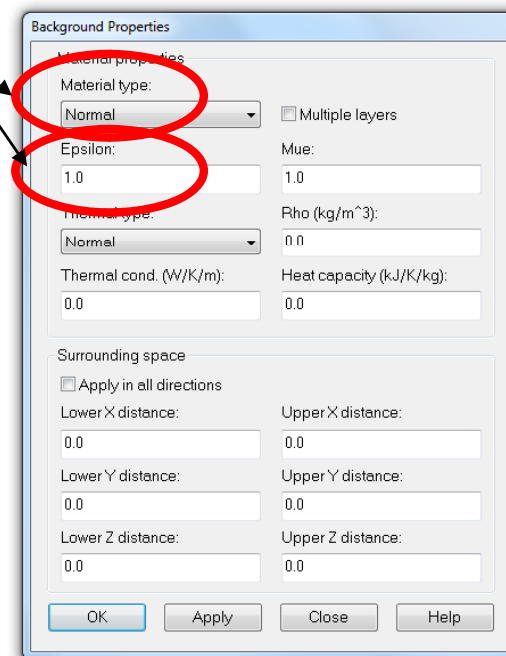
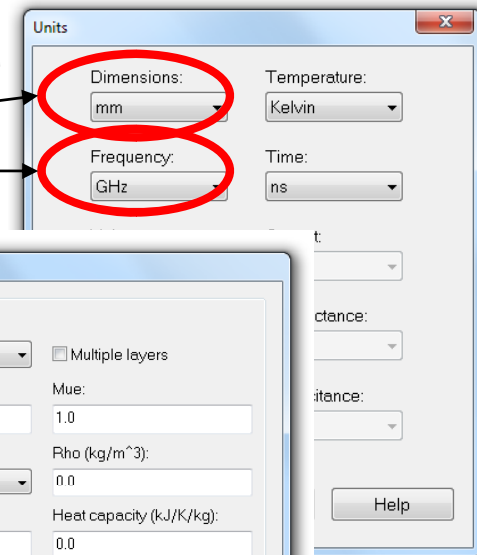


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# 1<sup>st</sup> Example: Dipole Antenna

## Initial Setup

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



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
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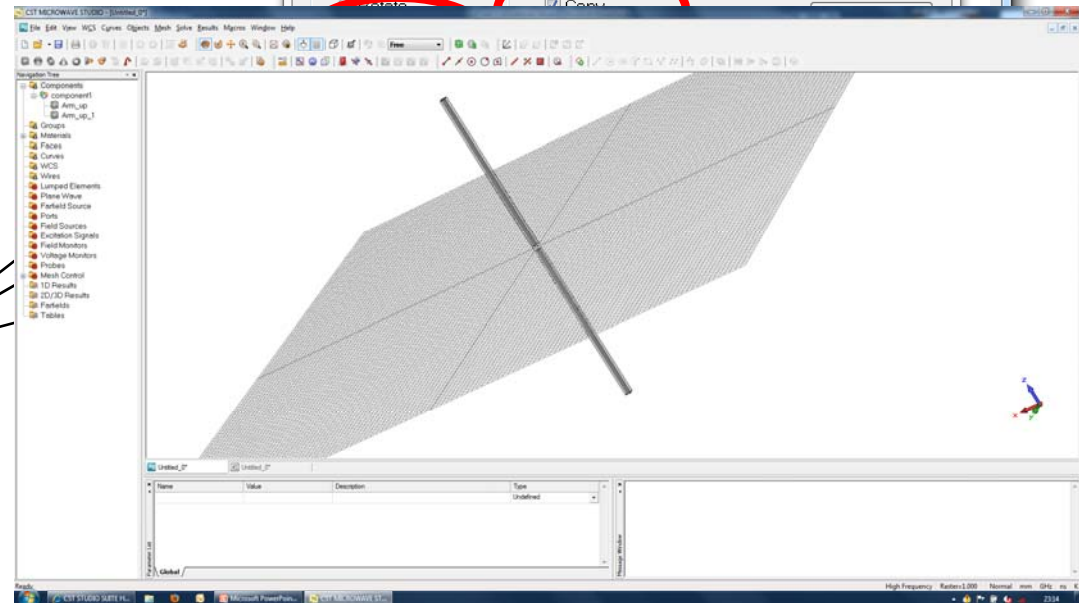
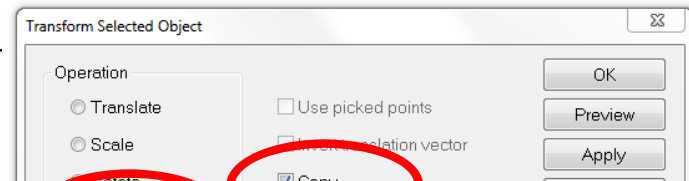
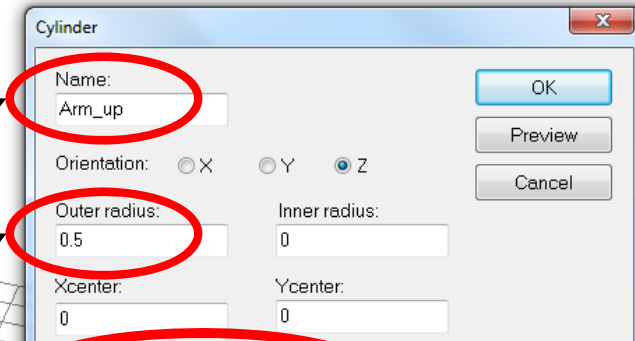


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# 1<sup>st</sup> Example: Dipole Antenna

## Geometry Drawing

- Draw cylinder 
- Name: "Arm\_up" 
- Dimensions (in mm) 
- Material: Perfect Electric Conductor – "PEC" 
- Select object in navigation tree 
- Object transform 



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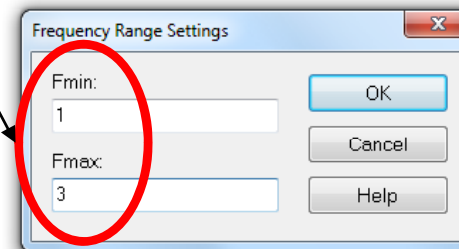
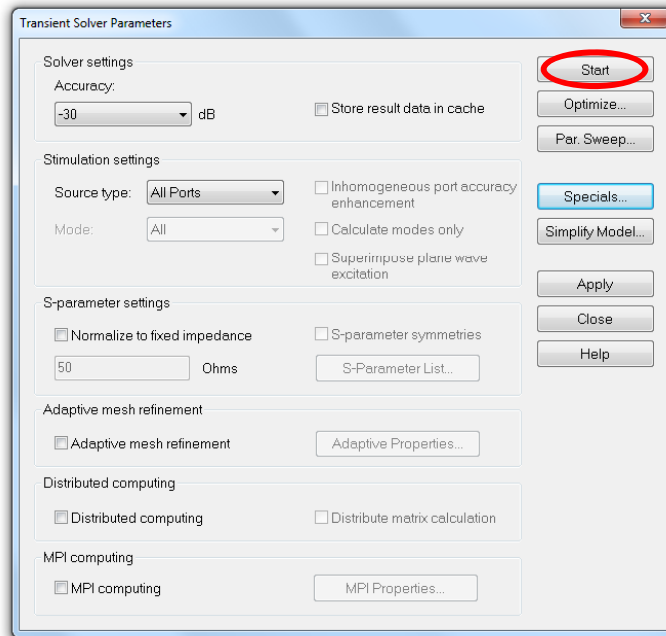
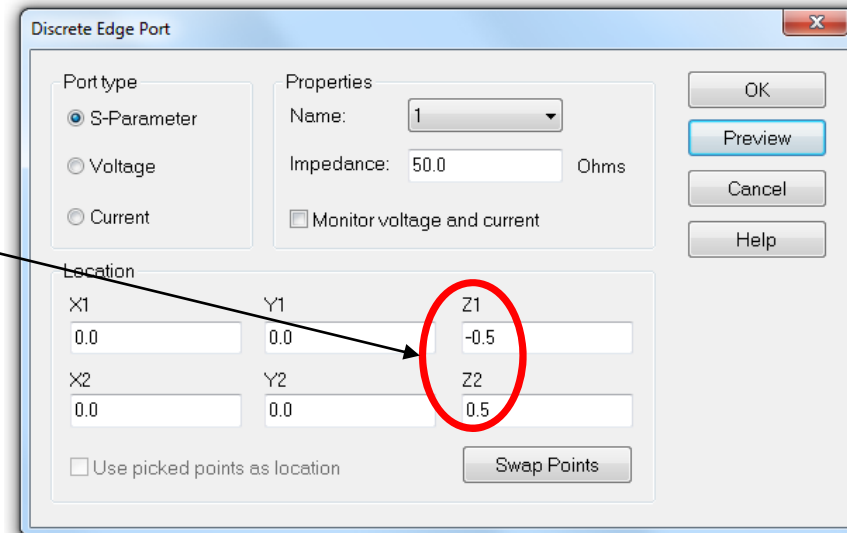
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# 1<sup>st</sup> Example: Dipole Antenna

## Excitation and Simulation Setup

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



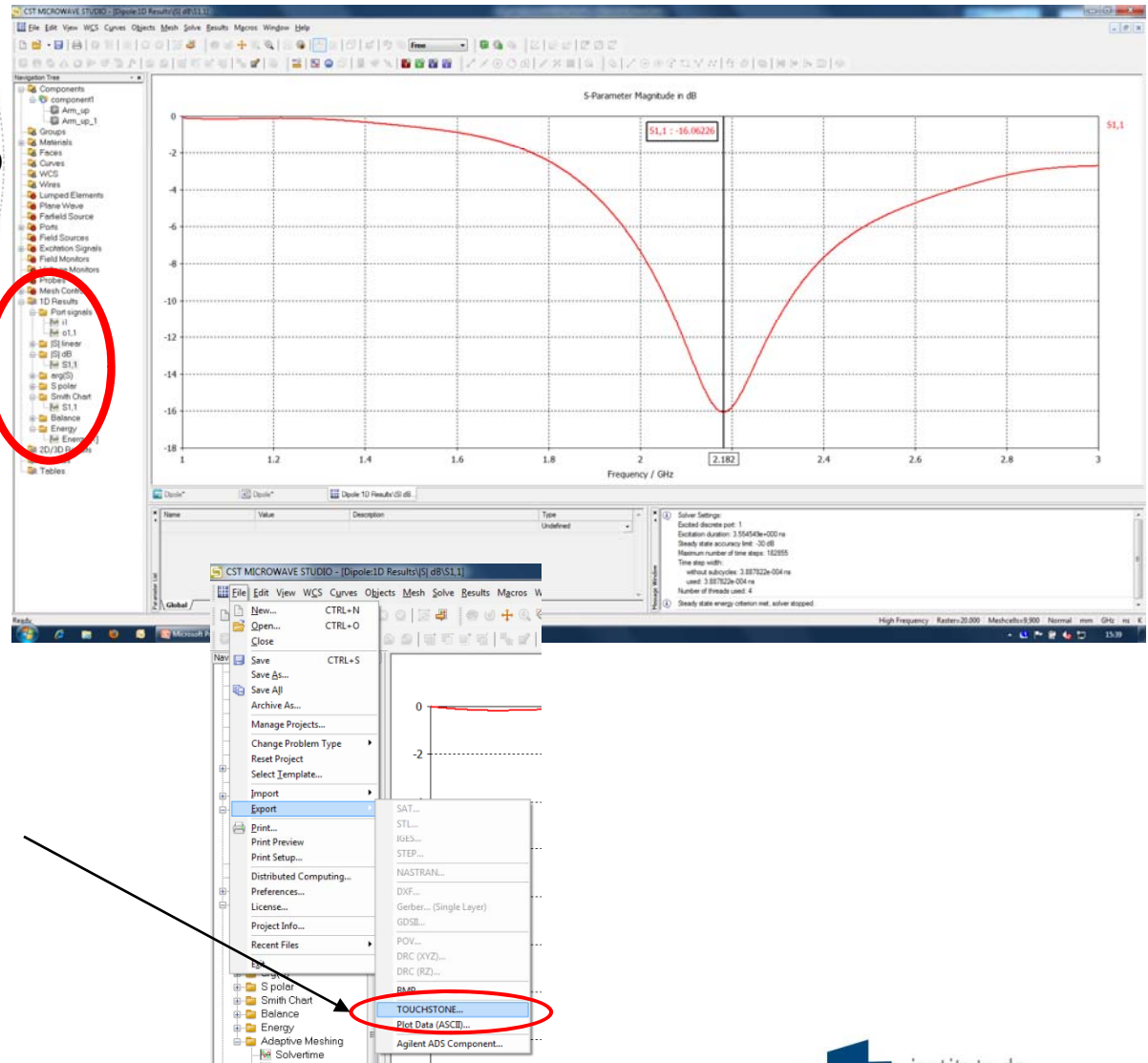


# 1<sup>st</sup> Example: Dipole Antenna

## 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

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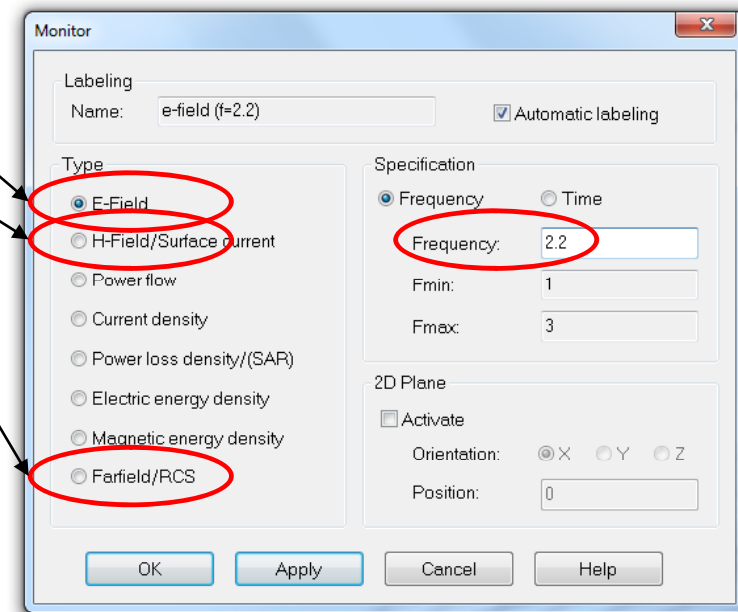
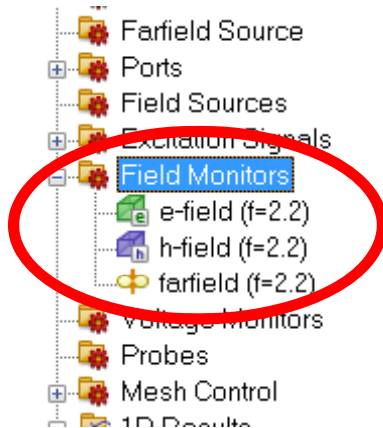
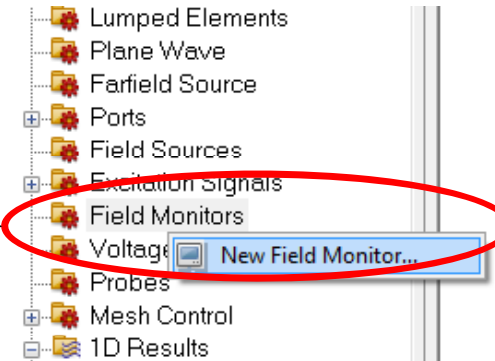
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# 1<sup>st</sup> Example: Dipole Antenna

## 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



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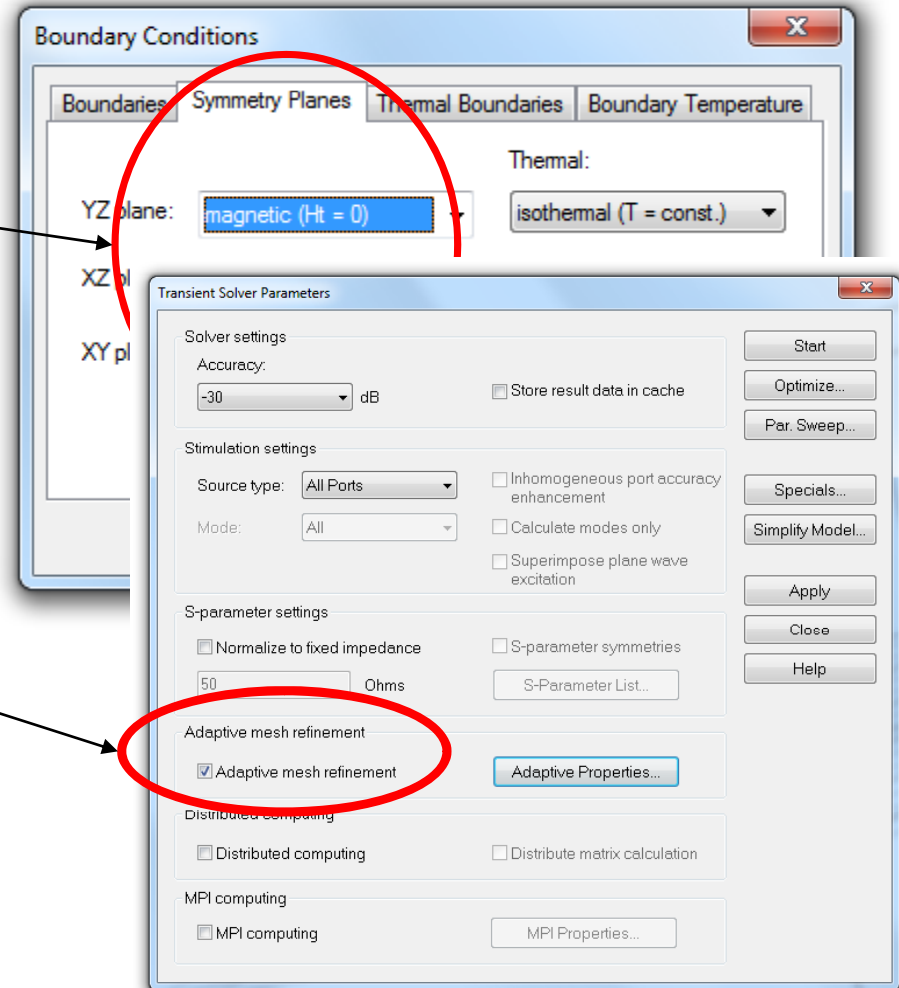


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# 1<sup>st</sup> Example: Dipole Antenna

## Improving simulation

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



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# 1<sup>st</sup> Example: Dipole Antenna

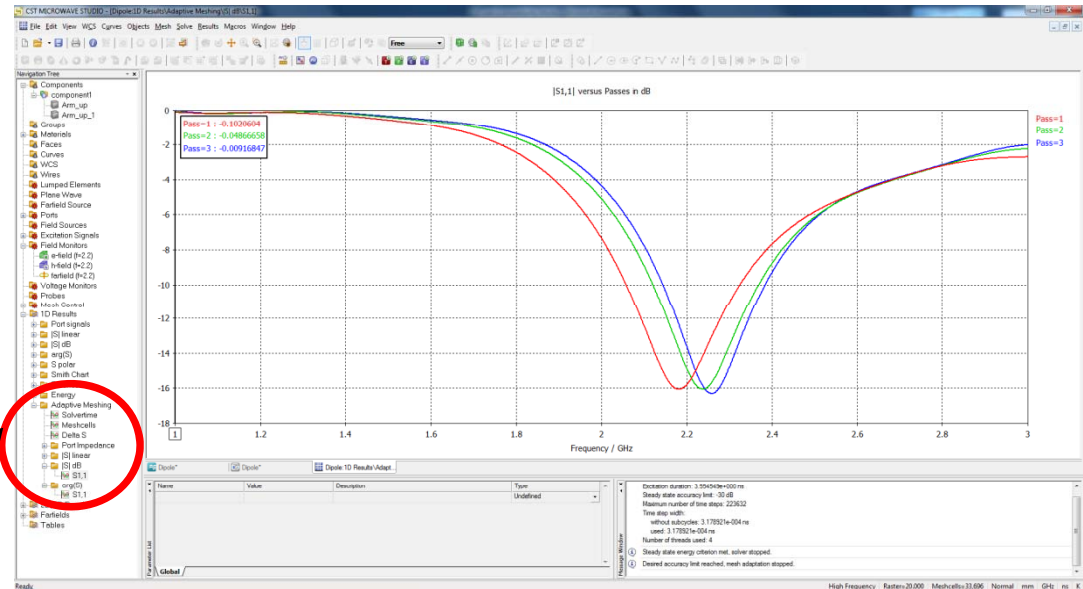
## Adaptive mesh results

➤ In navigation tree go to 1D Results -> Adaptive Meshing

- $S_{11}$
- Mesh cells
- Solver time

➤ Transient Solver 

- Deselect “Adaptive mesh refinement”
- Press Apply



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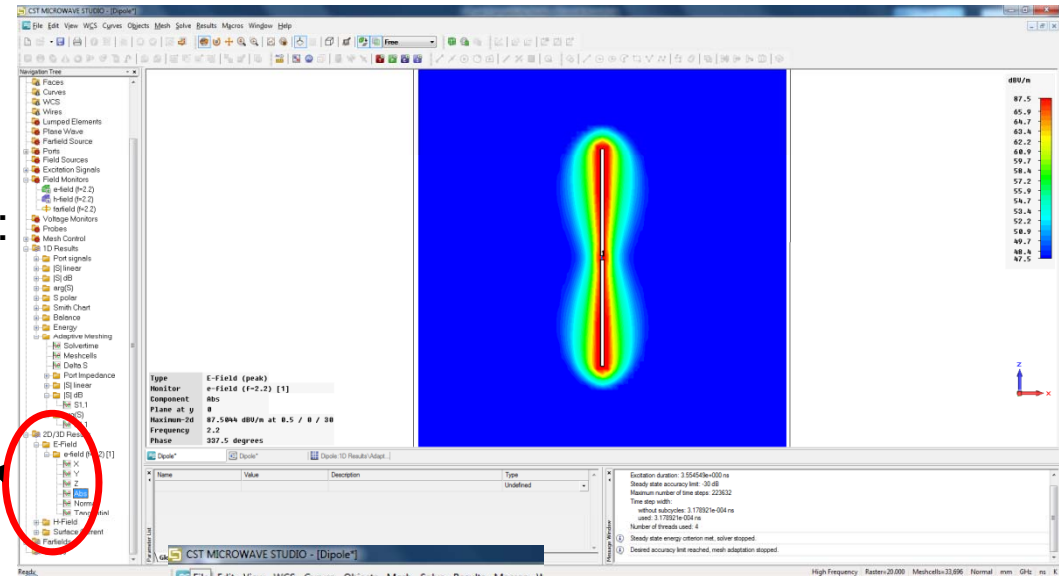


# 1<sup>st</sup> Example: Dipole Antenna

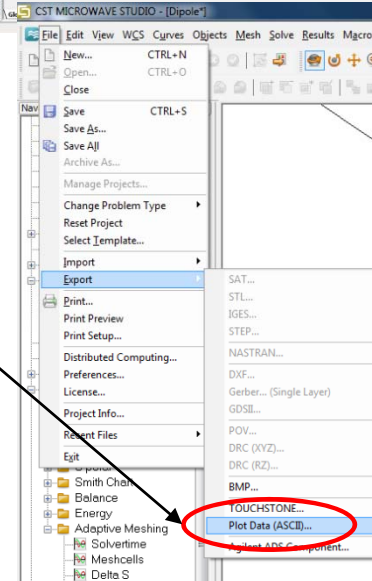
## Near-field results

➤ In navigation tree go to 2D/  
3D Results -> E-field or H-field:

- Field components
- Amplitudes
- Phases



➤ Can export results in txt  
file



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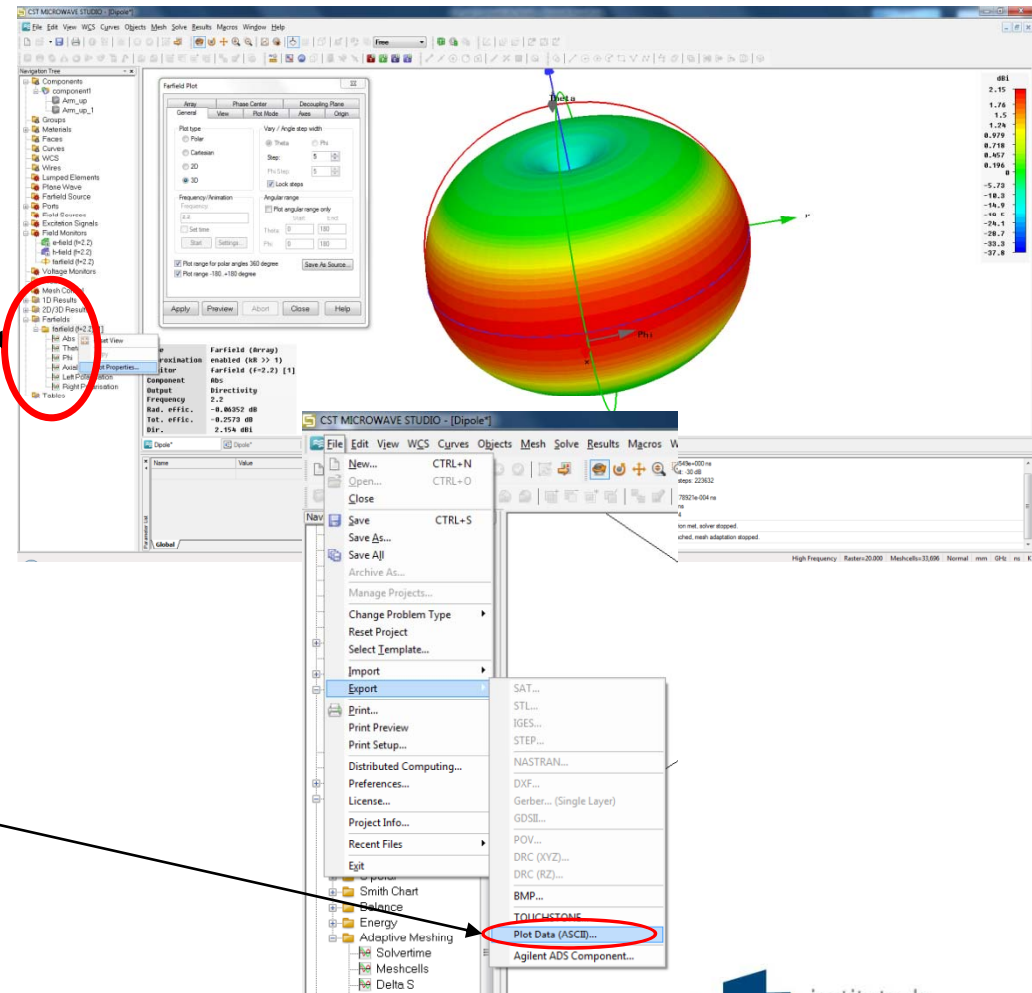
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# 1<sup>st</sup> Example: Dipole Antenna



## Far-field results

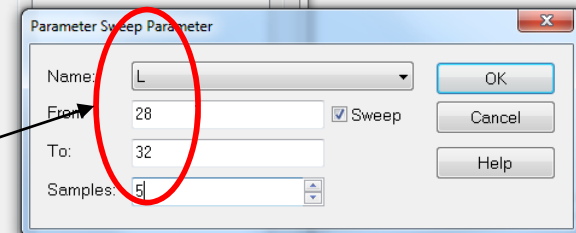
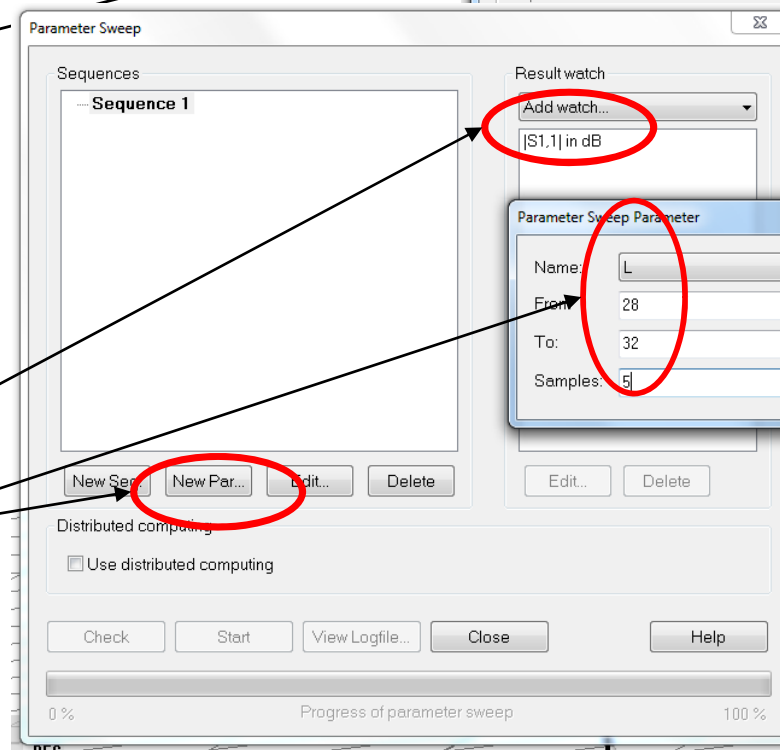
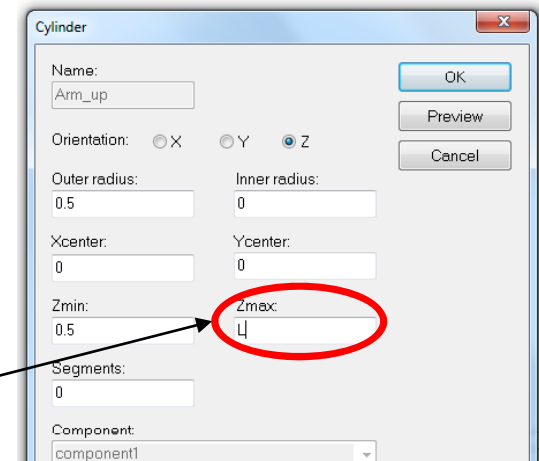
- In navigation tree go to Farfields:
  - Field components
  - Co-pol. and Cross-pol.
  - Polar, 2D or 3D
  - Rad. Efficiency
  - Directivity or Gain
- Can export results in txt file or in GRASP format



# 1<sup>st</sup> 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



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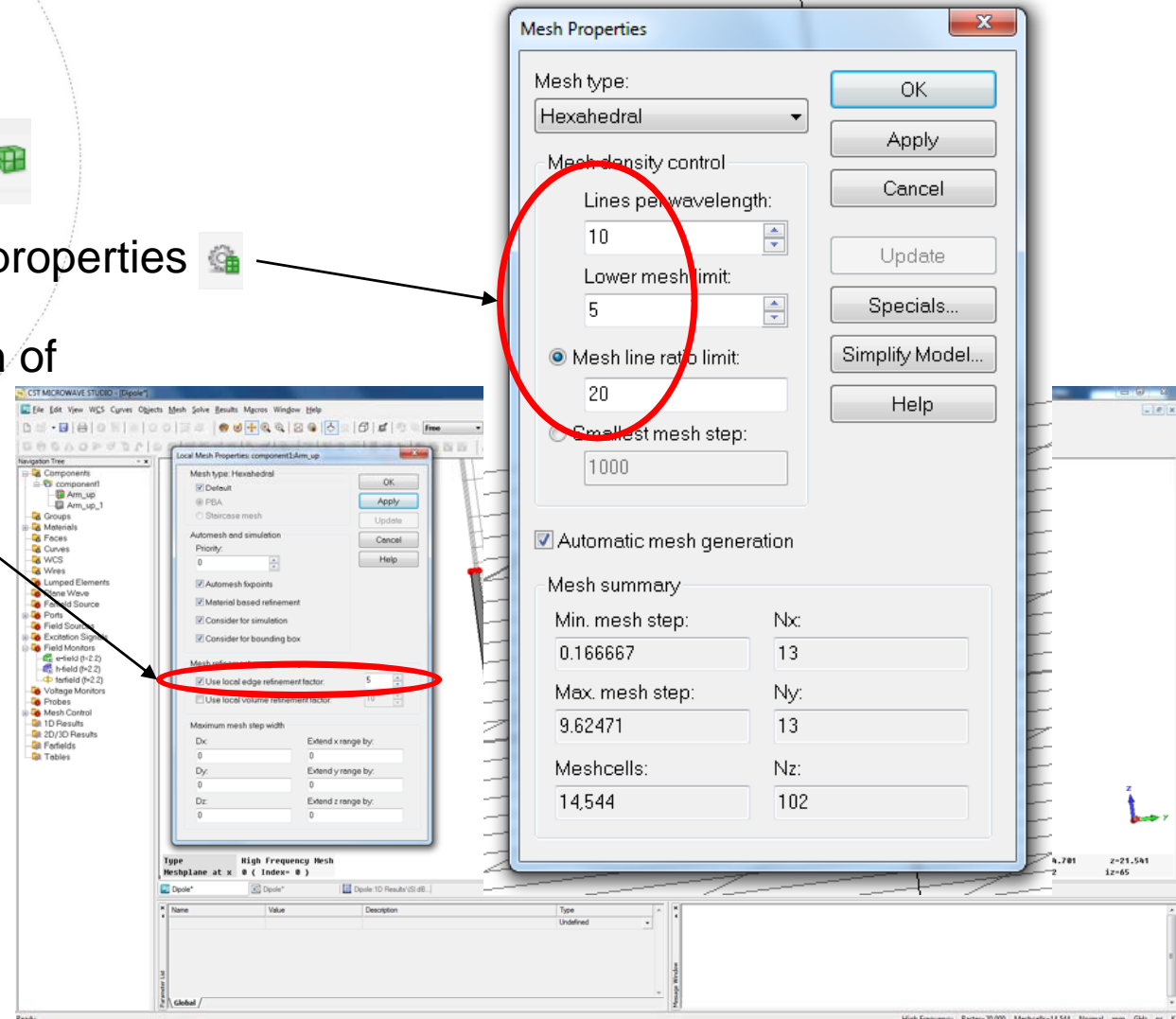


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# 1<sup>st</sup> Example: Dipole Antenna

## Mesh Operations

- Enable mesh view 
- View global mesh properties 
- Change local mesh of "Arm\_up" 



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# Visit CST Website

www.cst.com

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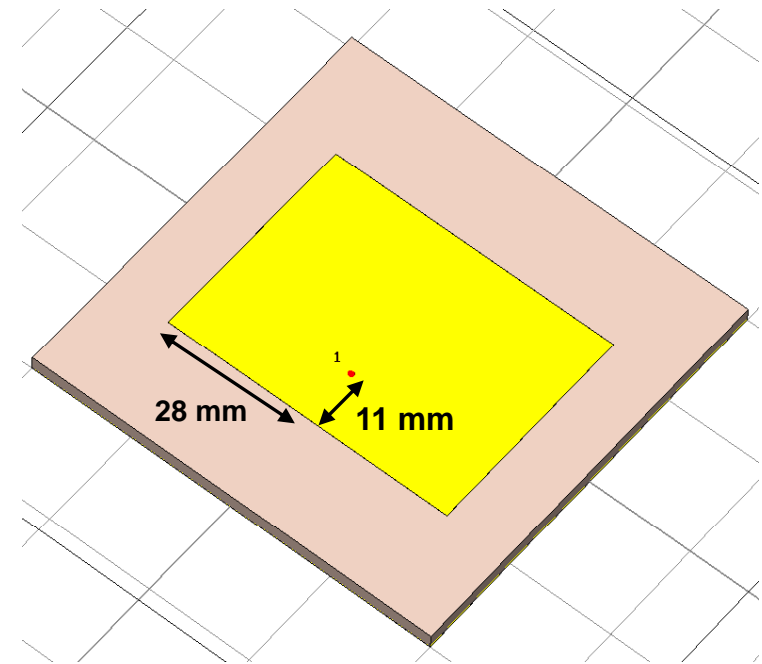


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## 2<sup>nd</sup> Example: Microstrip Patch

### 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

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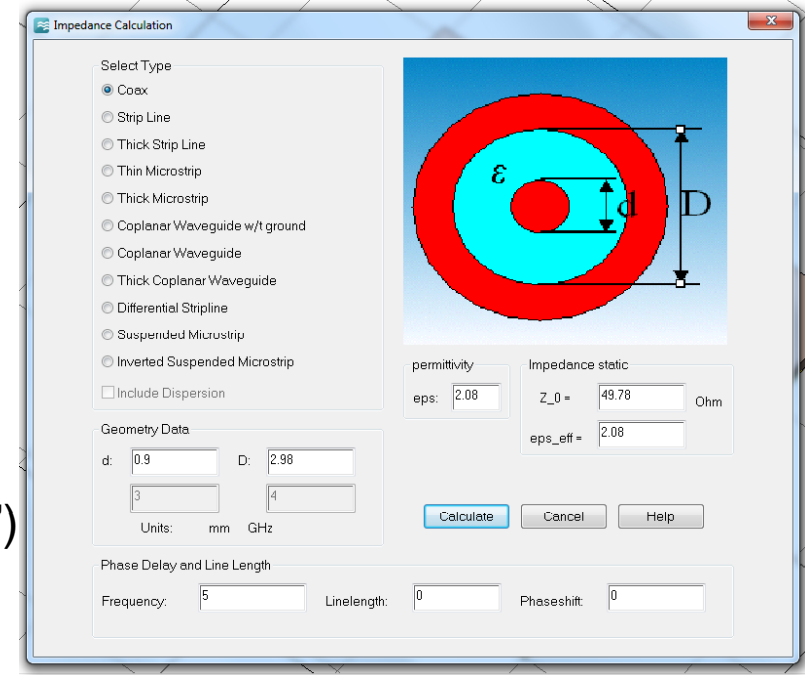


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## 2<sup>nd</sup> Example: Microstrip Patch

### 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 ( $\epsilon_r = 2.08$ )
Outer Conductor	1.8	-20	0	Copper

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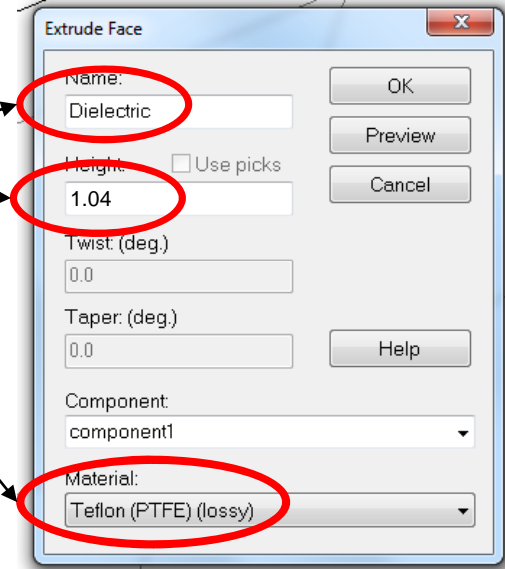
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## 2<sup>nd</sup> Example: Microstrip Patch

### 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 ( $\epsilon_r = 2.08$ )
Outer Conductor	1.8	-20	0	Copper

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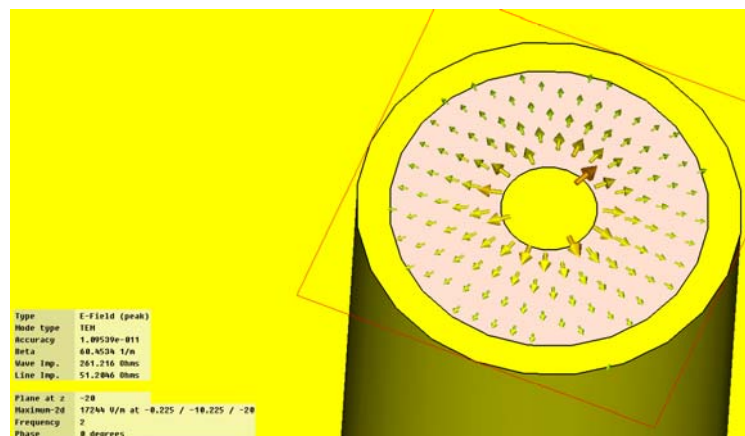
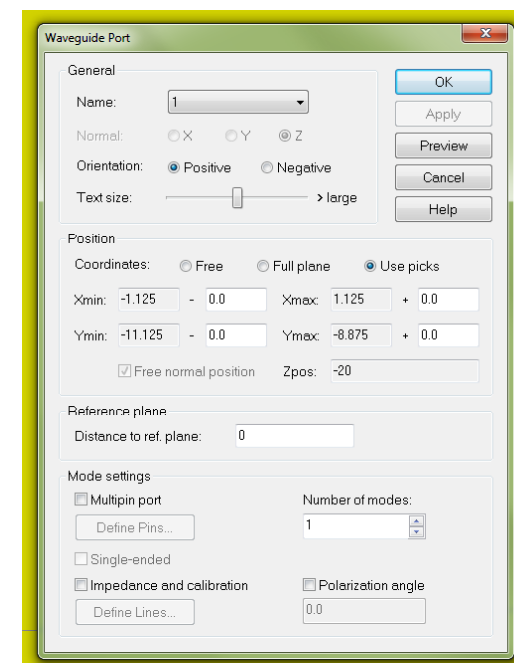
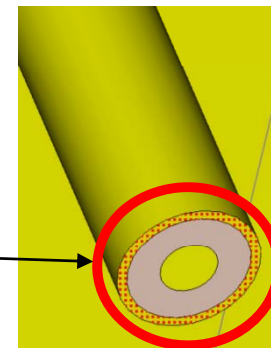
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## 2<sup>nd</sup> Example: Microstrip Patch

### 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



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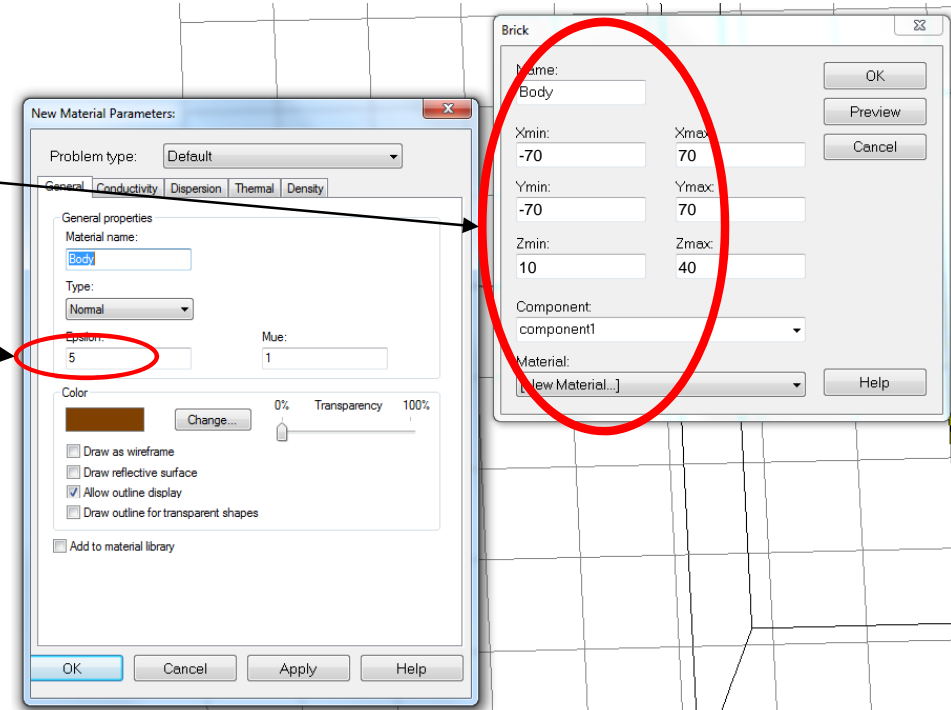
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## 2<sup>nd</sup> Example: Microstrip Patch

*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”  
 $\epsilon_r=5$  and  $\sigma=1$  (S/m)
- Run Transient Solver
- See  $S_{11}$  curve & radiation patterns



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# Questions ?



*After a CST simulation ...*

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