Voxel Tutorial

Wave Computation Tech.

Oct., 2017

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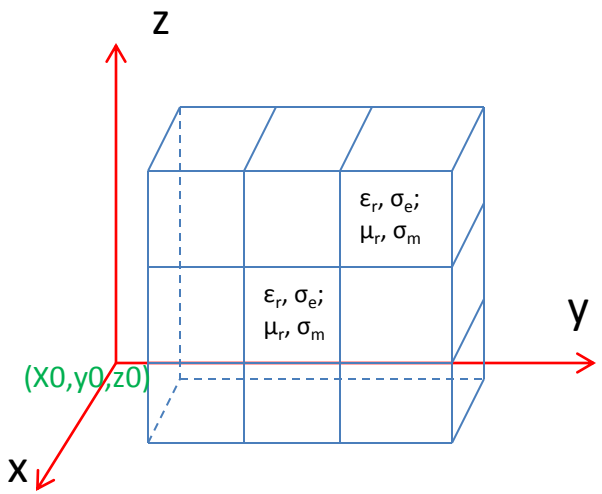
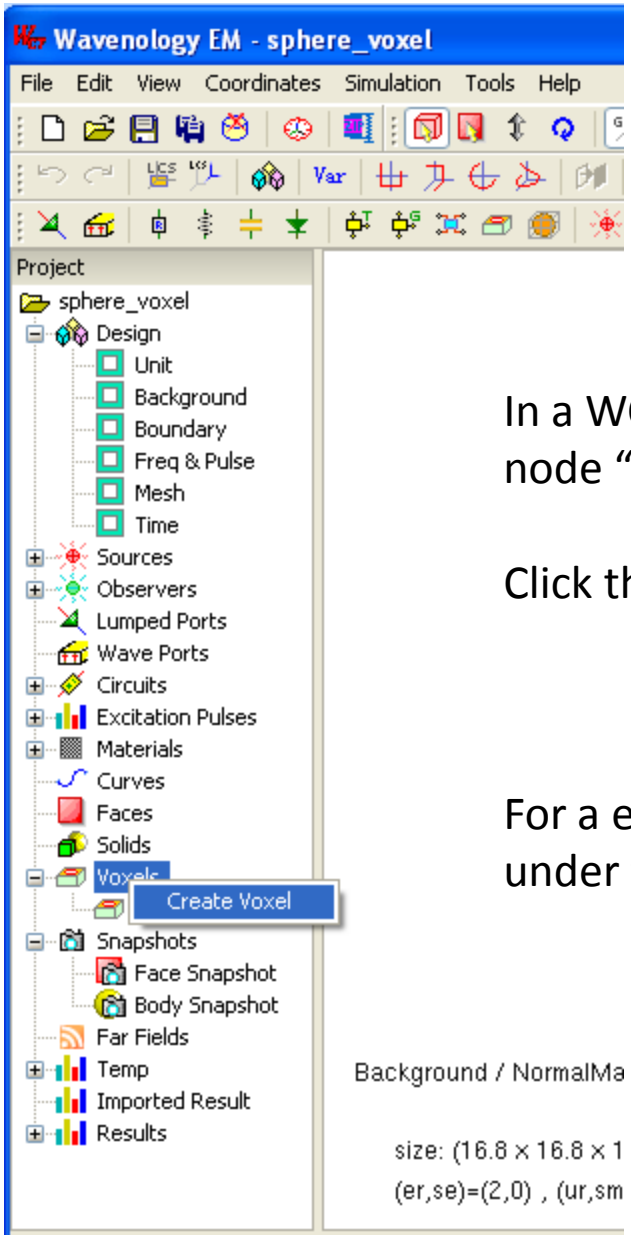
Voxel Definition

In WCT, the voxel is a rectangular volume. User ***must*** define
1) the volume start position,
2) uniform resolution in x, y and z direction
3) cells number in x, y and z direction
4) the material profile for each cell in the volume.



Note: Due to the simulation on voxel is an advance function of WCT, we will not cover the topics of the basic operations of WCT in this tutorial. Please refer to WCT manual and tutorial for these topics.



In a WCT project, right click mouse button on project tree node “Voxels”, a menu “Create Voxel” will be pop upped.

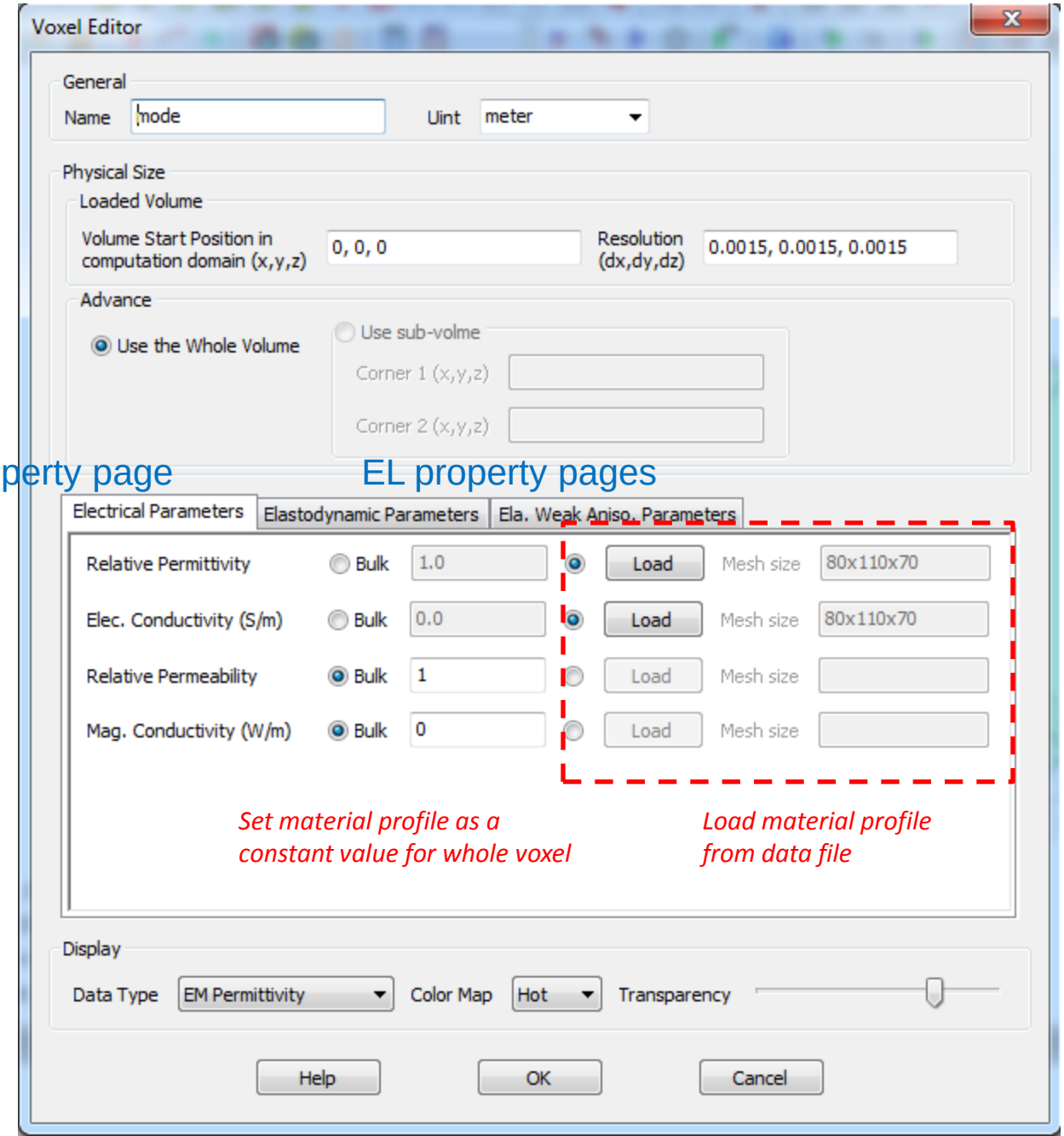
Click this menu, enter the ***Voxel Editor***.

For a existing voxel in a project, double click the voxel item under the treenode “Voxels”, user can enter the ***Voxel Editor***.

Voxel Editor

Voxel Name

Voxel volume start position

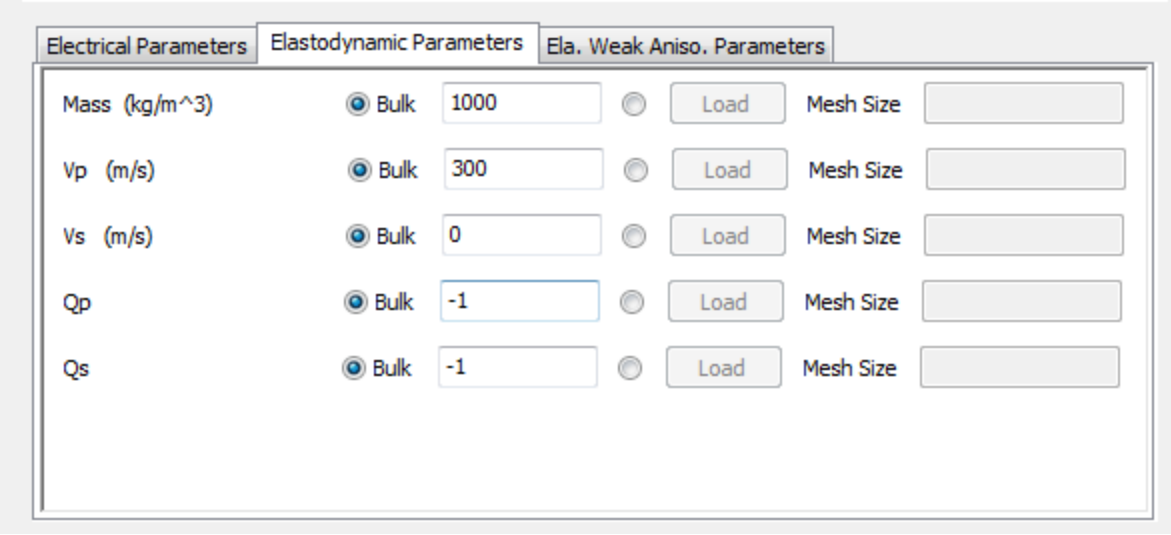


Unit for Voxel size & resolution

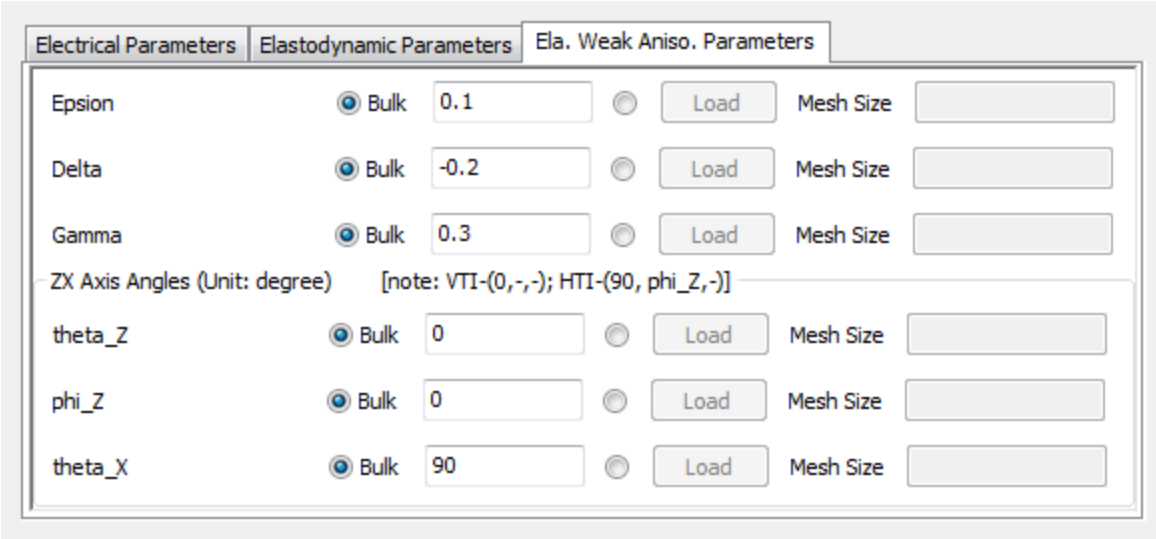
Voxel resolution

The number of cells in each direction. These values are read from data file.

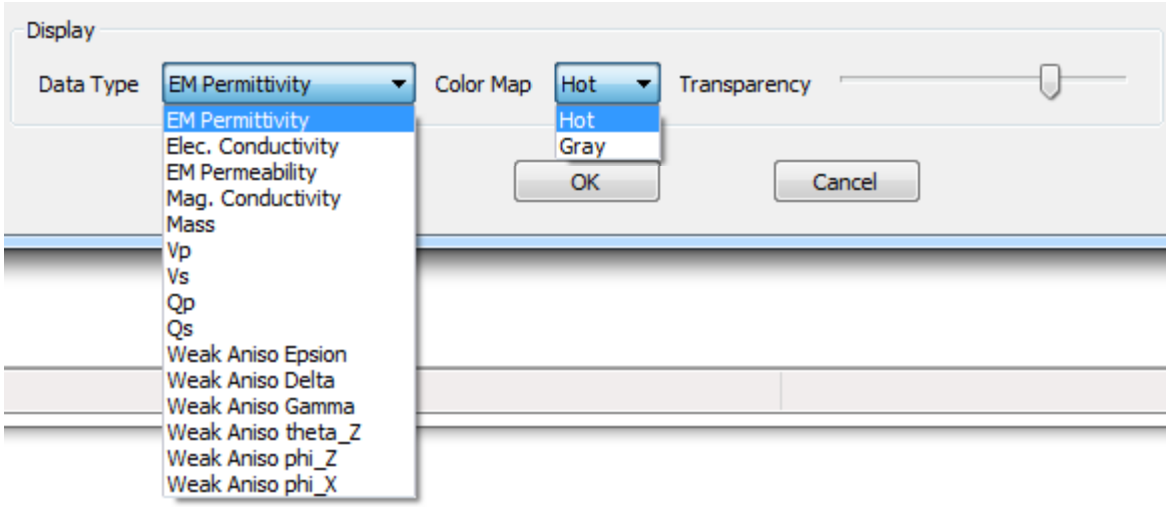
Elastic: Iso/visco-elastic parameters



Elastic: Weak anisotropic parameters



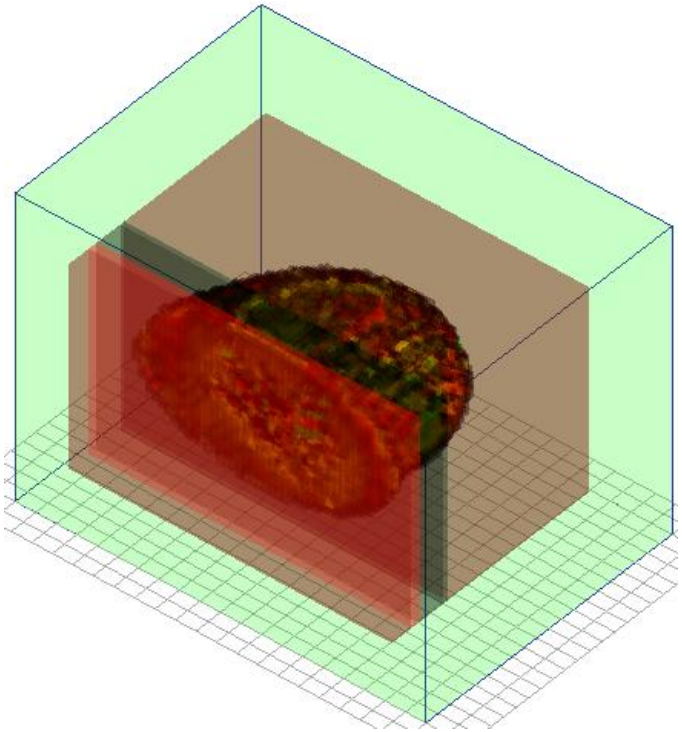
3D brief displaying control for GUI 3D canvas

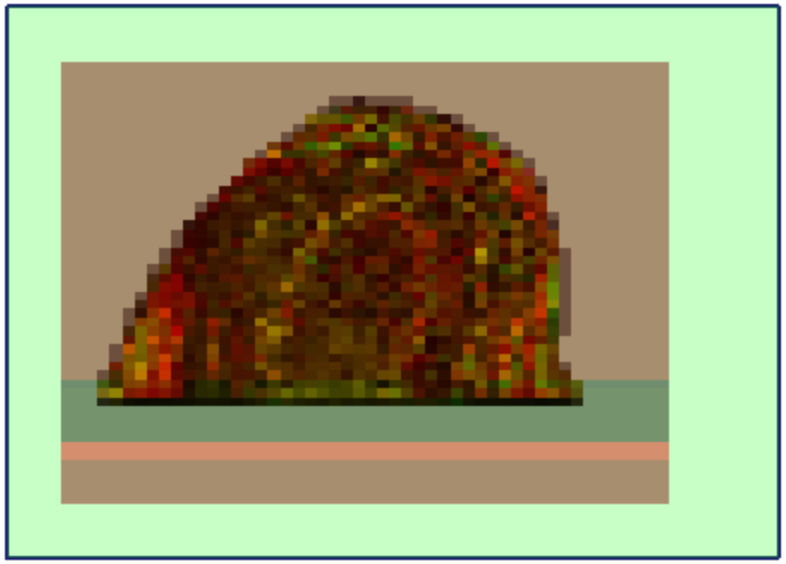


Displaying of Voxel in WCT GUI

(1) 3D Display

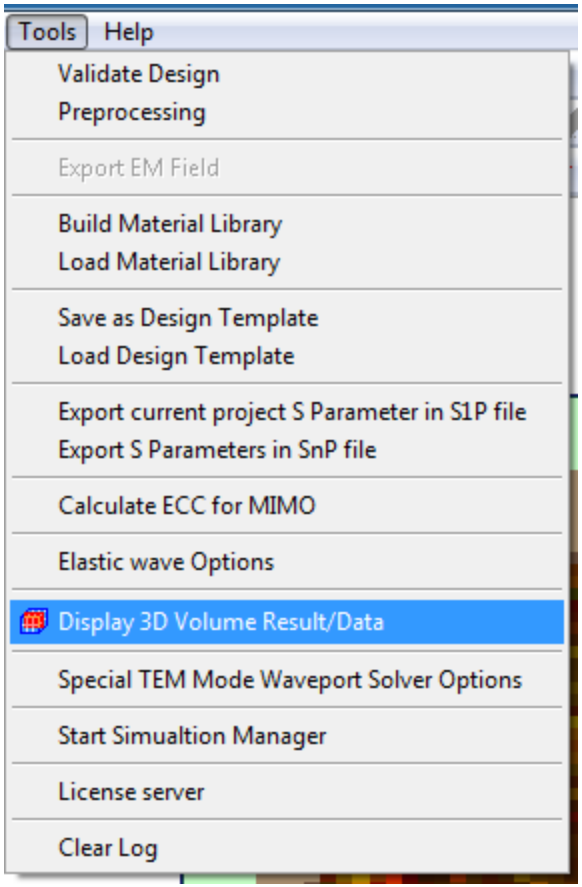
Following is an example of the 3D voxel brief displaying in GUI's 3D canvas. This voxel is a digital breast model from UWCEM Numerical Breast Phantoms Repository

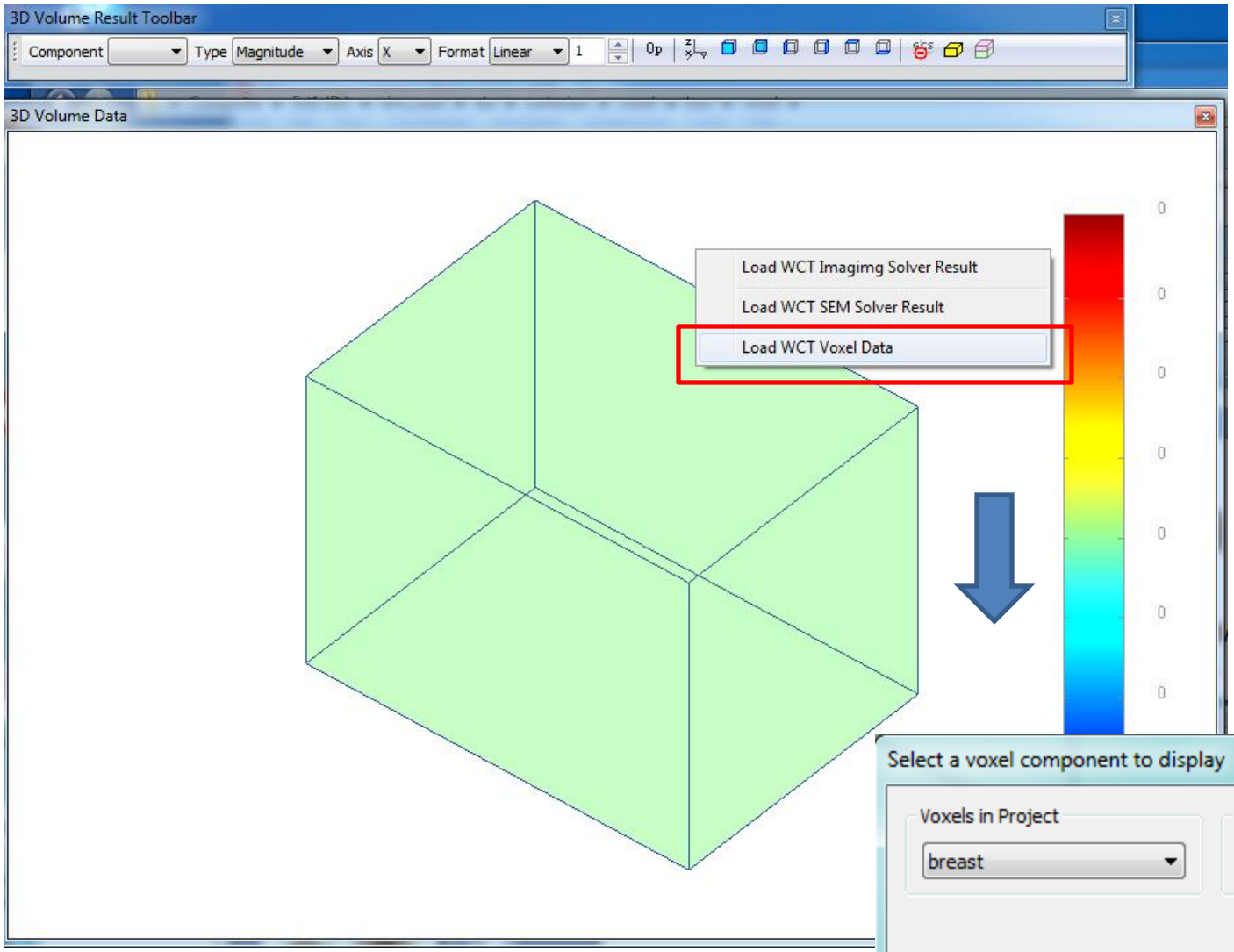




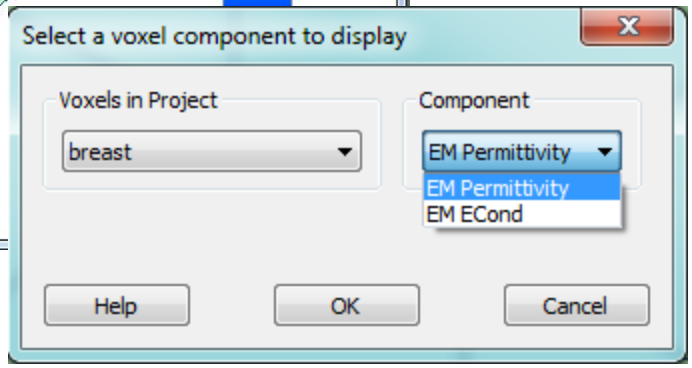
(2) 2D High Resolution View

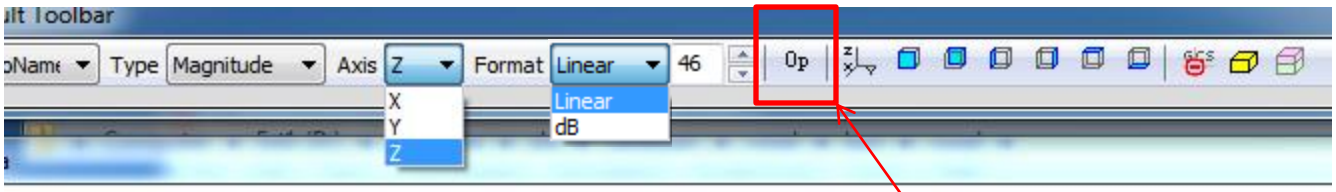
User can use “Display 3D Volume Result/Data” functionality to show voxel in a high resolution 2D cross-section mode.





User need to determine which voxel and what kind of parameter will be shown

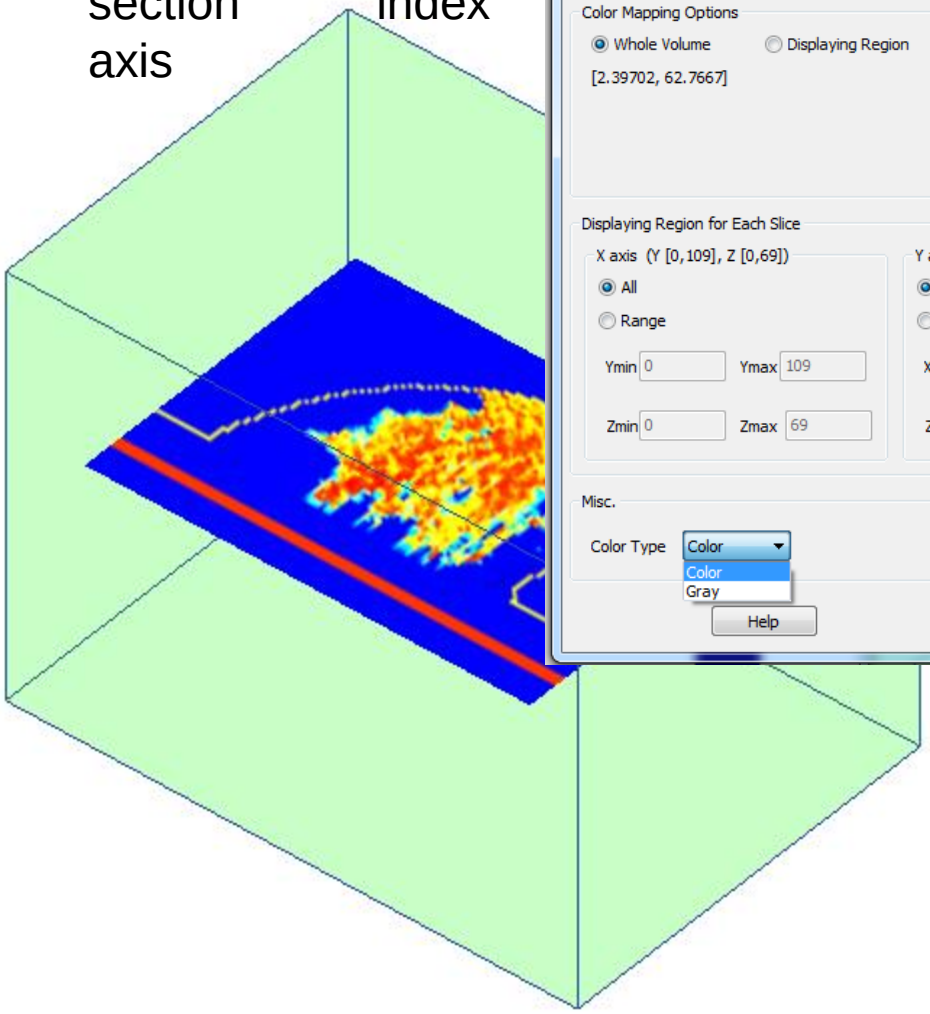


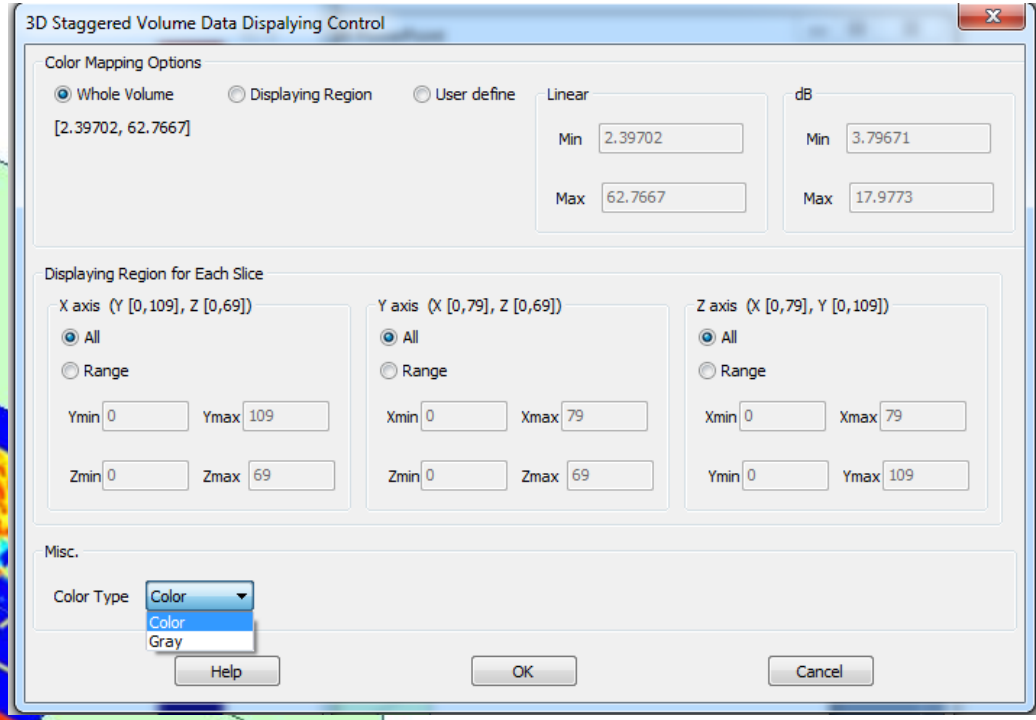


Displaying control

Cross-section axis

Frame index



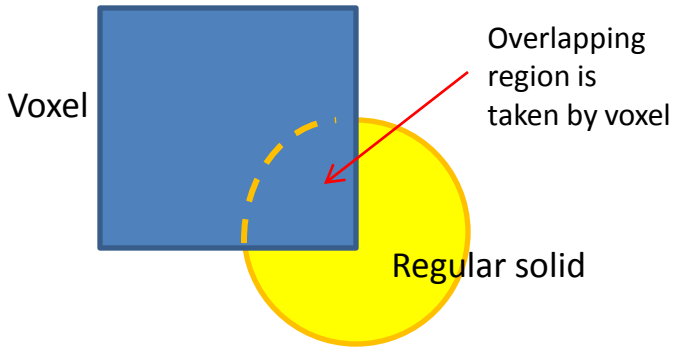


Other Information

1) There can be multiple voxels in a project.

2) If a voxel has overlapping region with regular solids,

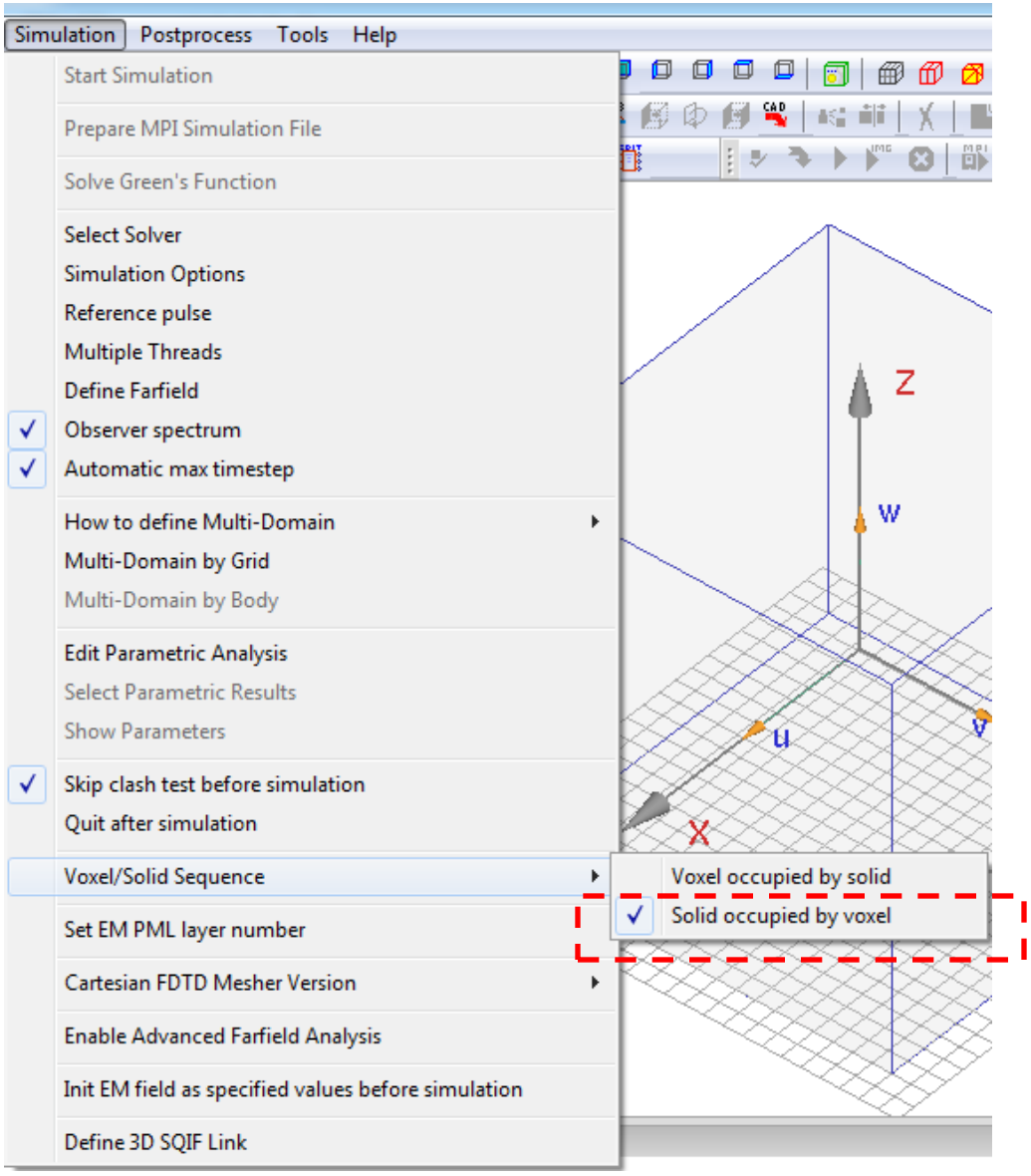
2.1) By default, WCT will use the material profile from voxel.



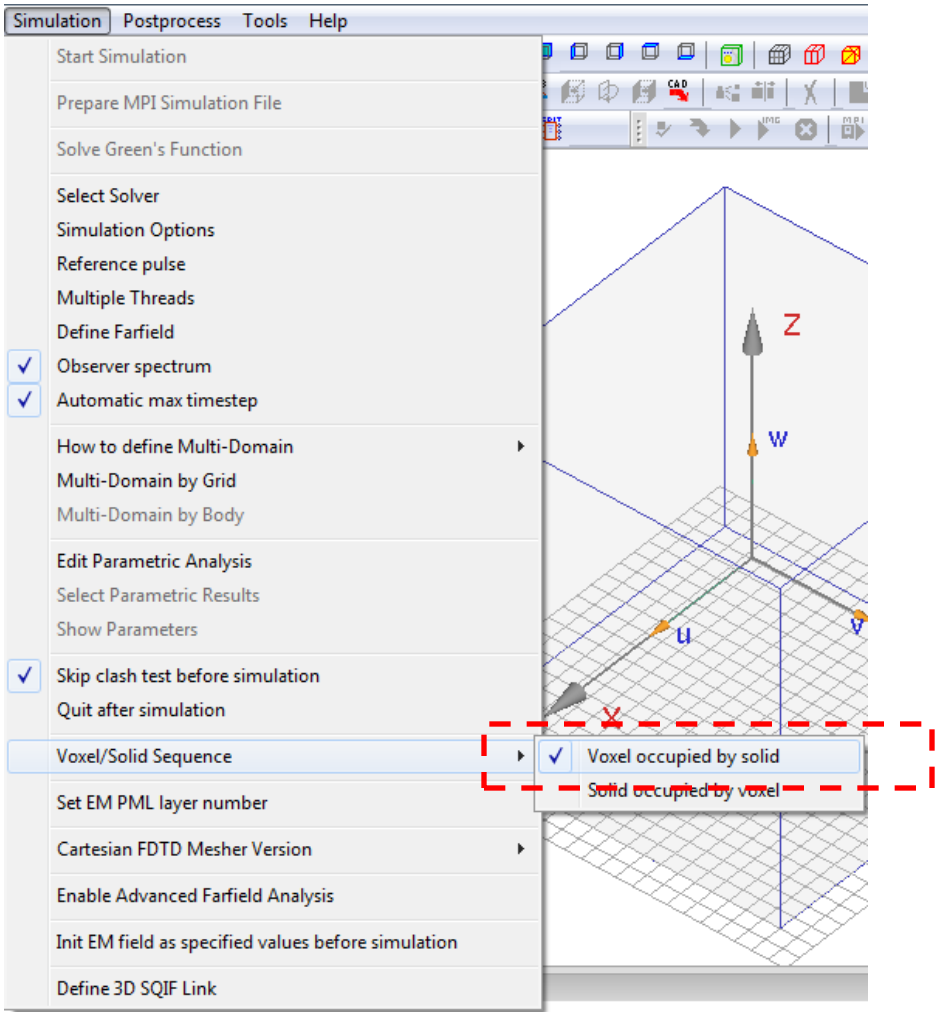
This default option is set though menu:

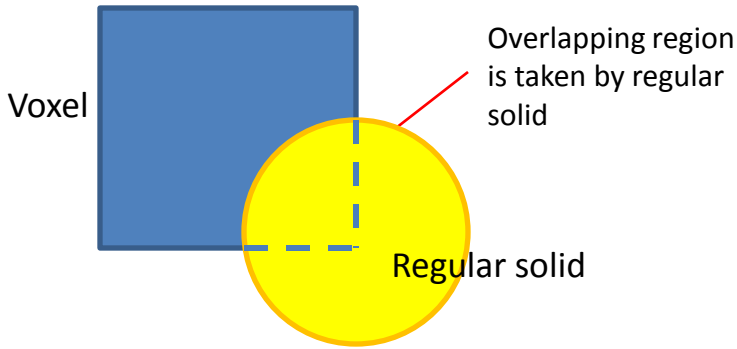
Simulation->***Voxel/Solid Sequence***

as next page


Simulation
Postprocess
Tools
Help
Start Simulation
Prepare MPI Simulation File
Solve Green's Function
Select Solver
Simulation Options
Reference pulse
Multiple Threads
Define Farfield
Observer spectrum
Automatic max timestep
How to define Multi-Domain
Multi-Domain by Grid
Multi-Domain by Body
Edit Parametric Analysis
Select Parametric Results
Show Parameters
Skip clash test before simulation
Quit after simulation
Voxel/Solid Sequence
Set EM PML layer number
Cartesian FDTD Mesher Version
Enable Advanced Farfield Analysis
Init EM field as specified values before simulation
Define 3D SQIF Link
Voxel occupied by solid
Solid occupied by voxel
Z
W
U
V
X

2.2) But user can switch to use the material profile from object. In this situation, it is equivalent to place solid in the voxel region.

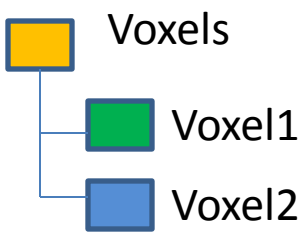


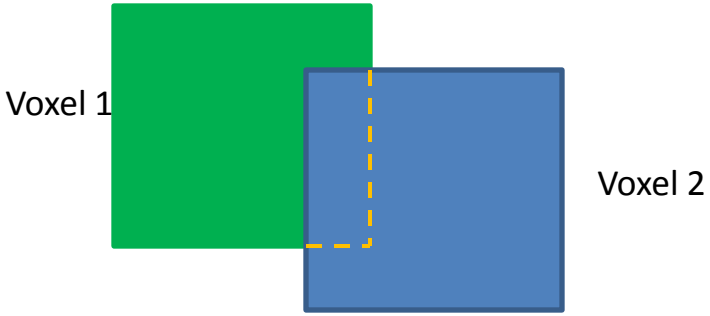


Note: this voxel sequence modification capability is enabled in **EM** solver only.

For current ***EL*** solver, this option will be skipped.

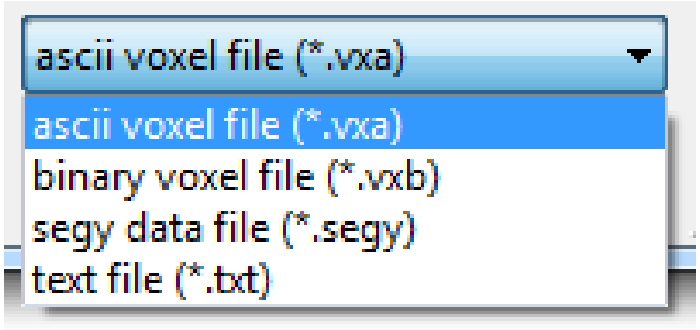
3) If a voxel has overlapping region with another voxel , WCT will use the material profile from the later voxel in the tree.





Voxel Input Data File Format

1) The data file for a voxel parameter can be
   1) ASCII text file, suffix as “txt”
   2) WCT internal Voxel data file, ASCII format, suffix as “vxa”
   3) WCT internal Voxel data file, binary format, suffix as “vxb”
   4) SEGY format, suffix as “segy”



2) For the ASCII text file (txt), the format is:

Line index	Meaning
1	Cell number in x direction (integer)
2	Cell number in y direction (integer)
3	Cell number in z direction (integer)
4	Parameter for cell (0,0,0)
.	Parameter for cell (0,0,1)
.	….
.	Parameter for cell (0,1,0)
.	Parameter for cell (0,1,1)
.	….

The ***for-loop*** to read parameter for each cell is:

```
for x;
    for y;
       for z;
            ……
       end z;
    end y;
end x;
```

3) File examples (from demo case (2))

A data file for ε_r

```
4
1
2

2.0
1.0

3.0
1.0

1.0
1.0

1.0
1.0
```

4 x cells, 1 y cell, 2 z cells
Totally 8 cells

Following 8 floating numbers is the parameter for each cell

A data file for σ_e

```
4
1
2

0.0
1e20

10.0
0.0

1e20
1e20

1e20
1e20
```

User can insert empty line between two lines

Note: for PEC and PMC, ideally they should be a infinite number. In WCT voxel data, user need use a high conductivity value to make an approximation. Here, we set σ_e as $1e^{20}$ to represent PEC material. But this value should be less than $1e^{30}$.

4) Wavenology ASCII voxel file (vxa), the format is:

parts	Meaning
Line 1	comment
Line 2	version
Next 3 lines	nx, ny, nz
Following N lines	N=nx*ny*nz; one value for one cell

The ***data sequence*** in the data block

```
for x;
    for y;
       for z;
            ……
       end z;
    end y;
end x;
```

5) Wavenology binary voxel file (vxb), the format is:

parts	Meaning
80 char	comment
int32	Major version
int32	Minor version
int32	nx
int32	ny
int32	nz
float32[N]	N=nx*ny*nz

The ***data sequence*** in the data block “float[N]”

```
for x;
    for y;
       for z;
            ……
       end z;
    end y;
end x;
```

Voxel Demo Cases

Part I: EM Solver

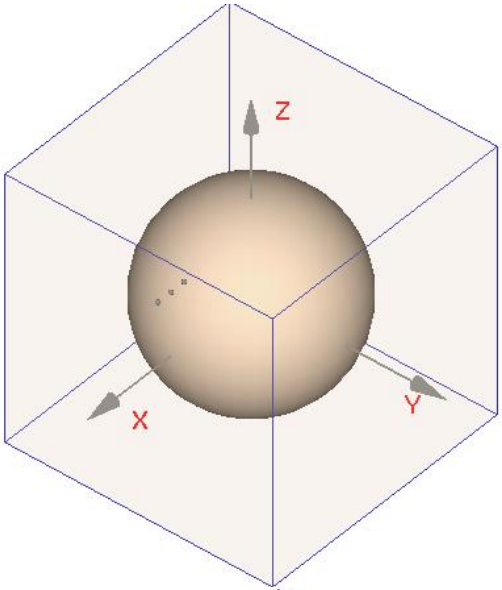
1) Transient response from a dielectric sphere

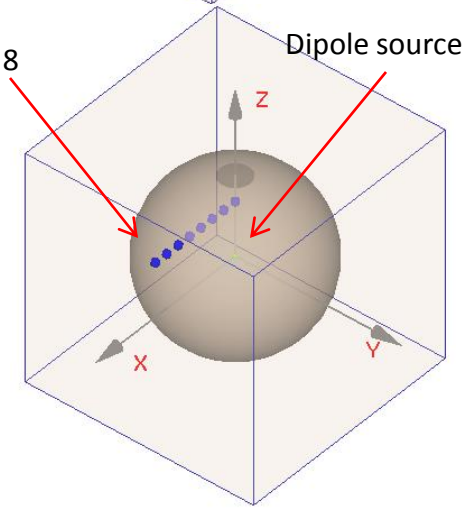
2) Transient response from multiple rectangular solids, including PEC solids

3) Simulation on a digital breast model

Case (1) Sphere

This case simulates a dielectric sphere, defined by voxel, in homogenous background.





Transparent view

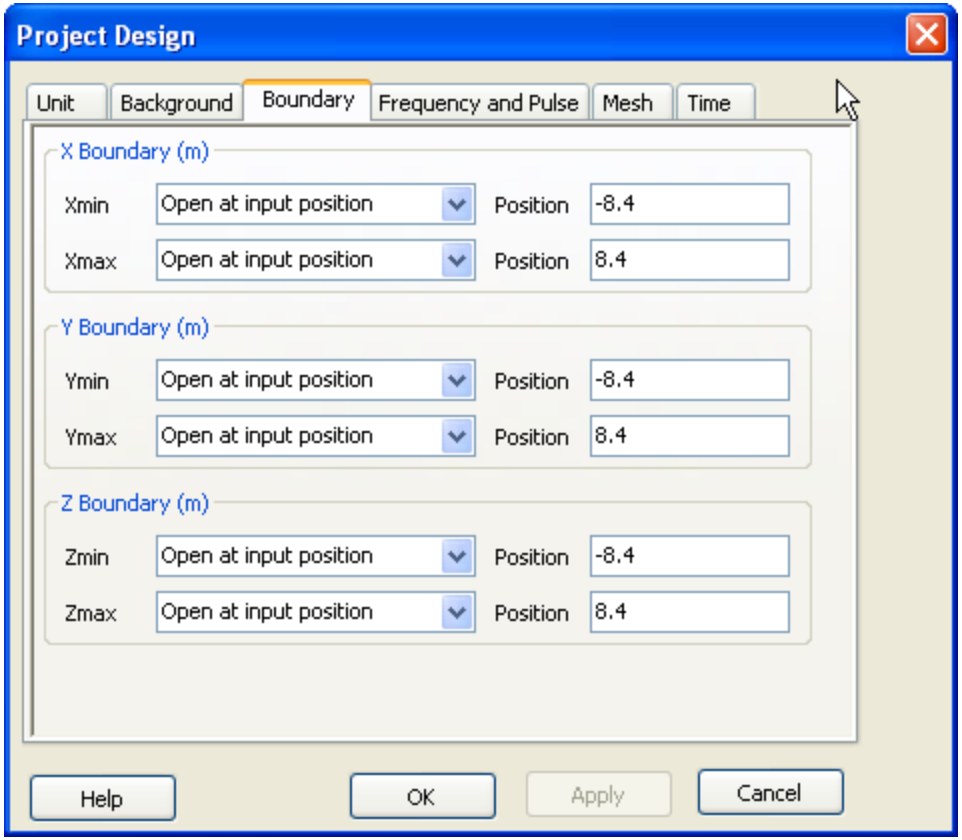
The left Fig. is WCT tutorial case “NormalSphere”, a dielectric sphere in homogenous background.

In this voxel case, we will replace the rectangular volume enclosing sphere by a voxel, and compare the transient response on receiver 8 with analytical solution.

Background: ε_r=2, σ_e=0; μ_r=2, σ_m=0
Sphere: ε_r=4, σ_e=0; μ_r=1, σ_m=0; r=6 m
Excitation: Ideal E dipole with 45.4K-21.6M Hz BHW pulse, *x* polarization.

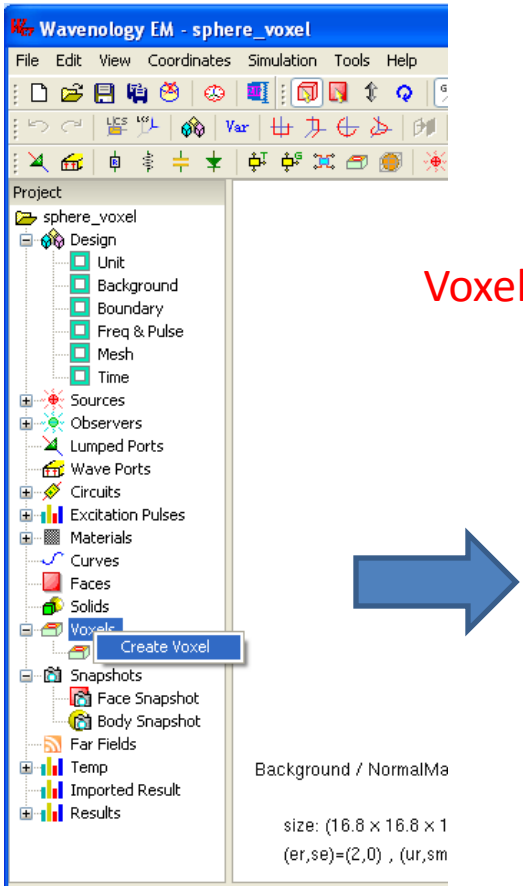
Steps:

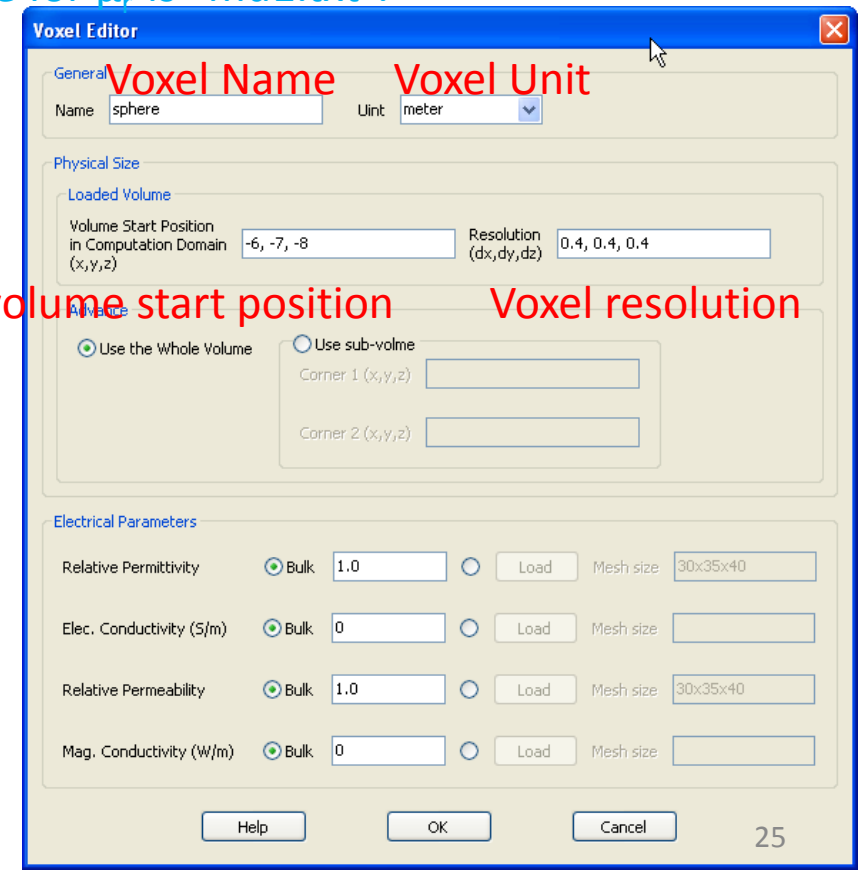
1) User can open the tutorial case “NormalSphere”, **SaveAs** a new case “SphereVoxel”
2) Change project boundary to “OPEN at input position”, as following Fig.



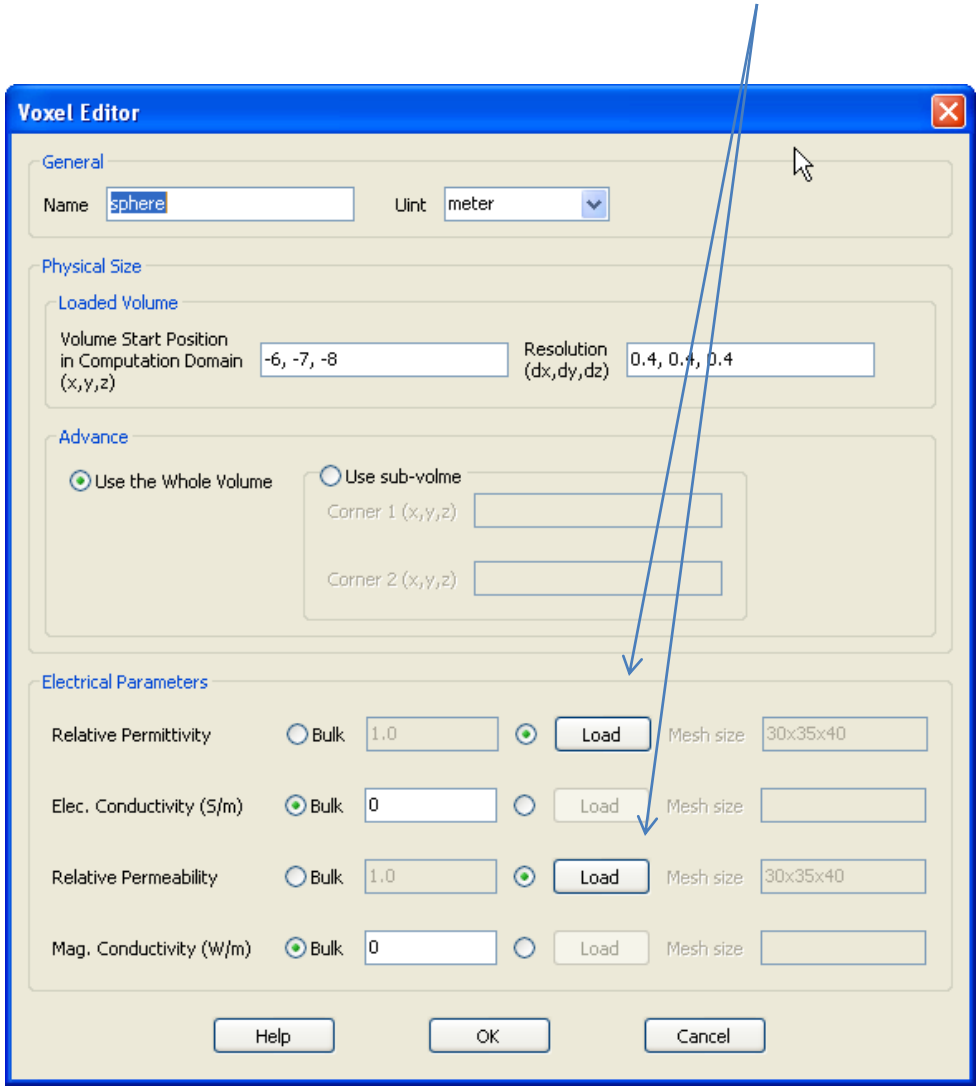
3) Delete the sphere.
4) Save the project.
5) Generate voxel data file for ε_r & μ_r .
   In demo cases folder: "\sphere \Sphere_voxel_resolution_0.4_auto_mesh\matlab\", there is a matlab example code to generate a voxel volume from (-6,-7,-8) to (6,7,8) m with a resolution 0.4 m at x, y and z direction.
   The data file for ε_r is "eps1.txt", The data file for μ_r is "mu1.txt".

6) Create a voxel.

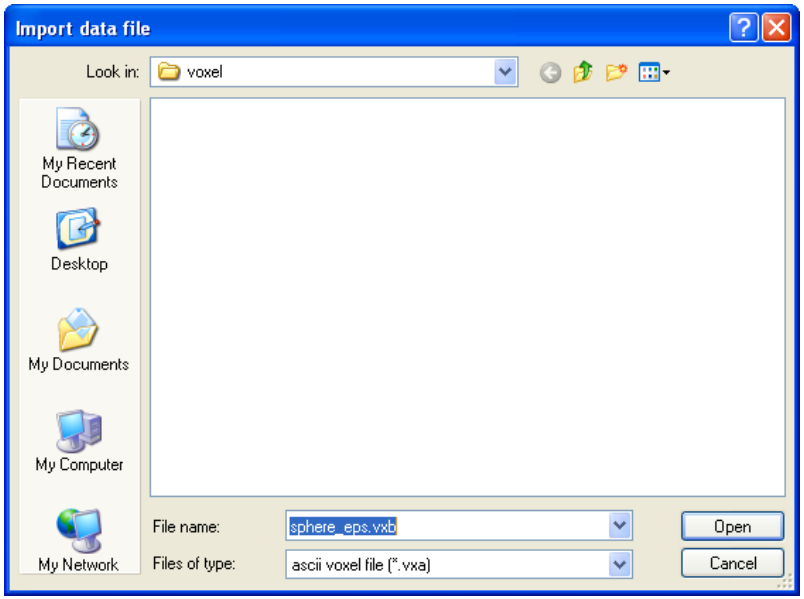




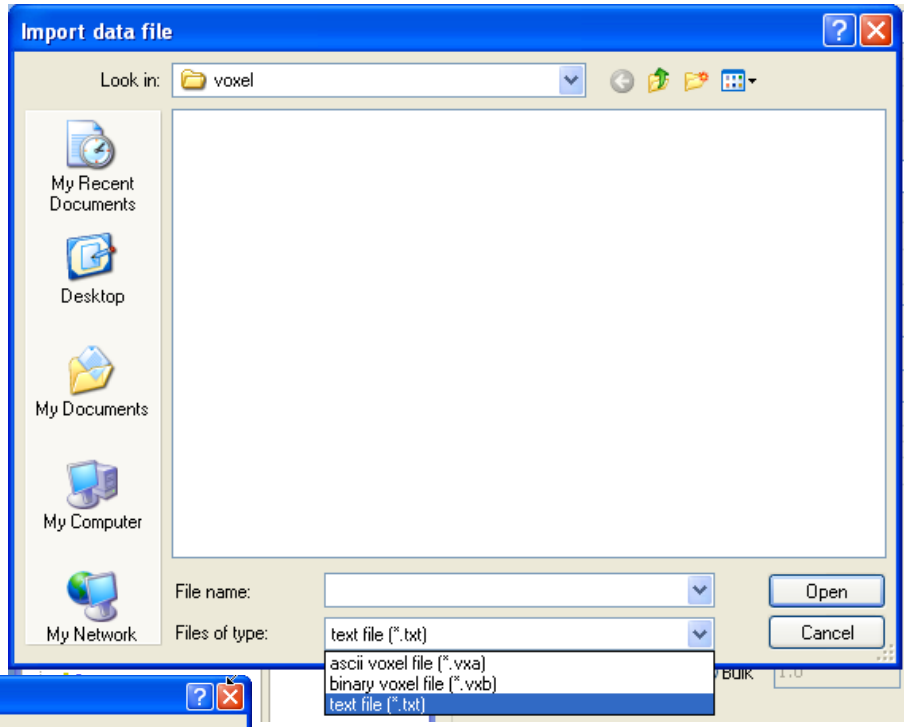
Switch “Relative Permittivity” & “Relative Permeability” to ***Load***



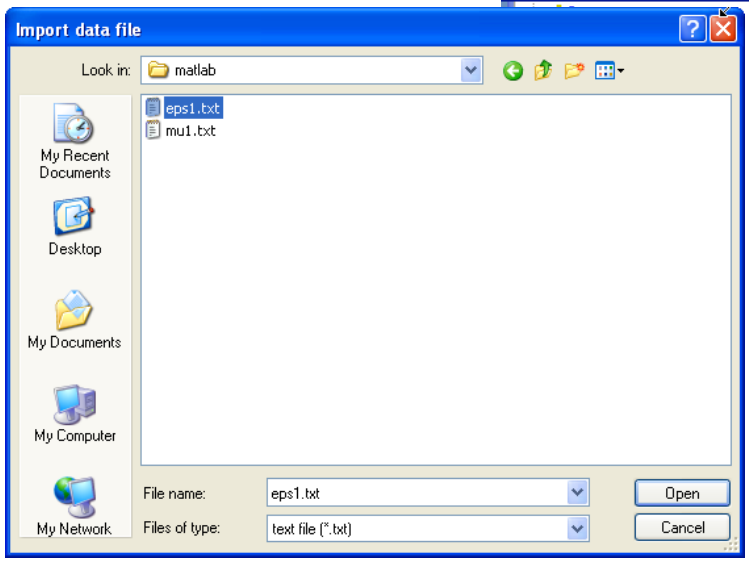
Click ***Load*** button to load file “eps1.txt” for Relative Permittivity
“mu1.txt” for Relative Permeability, separately.



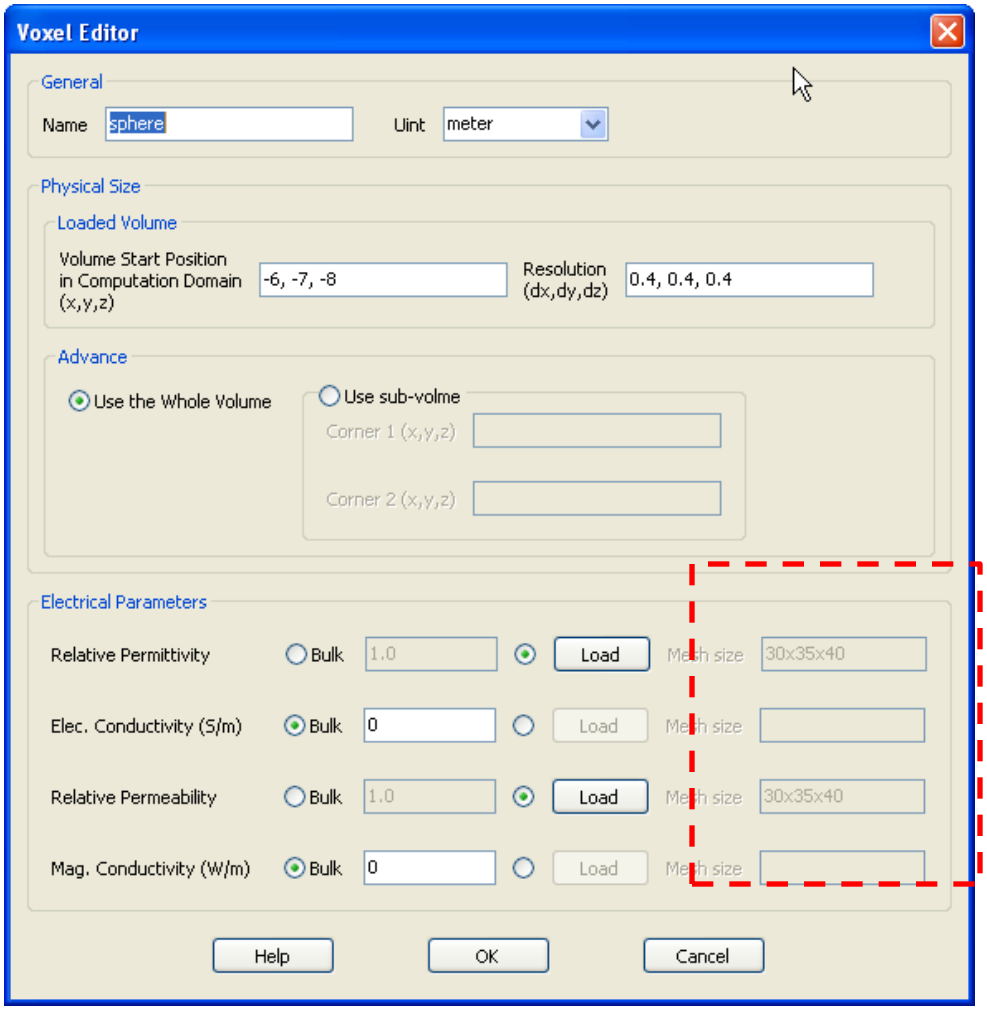
(1)



(2)



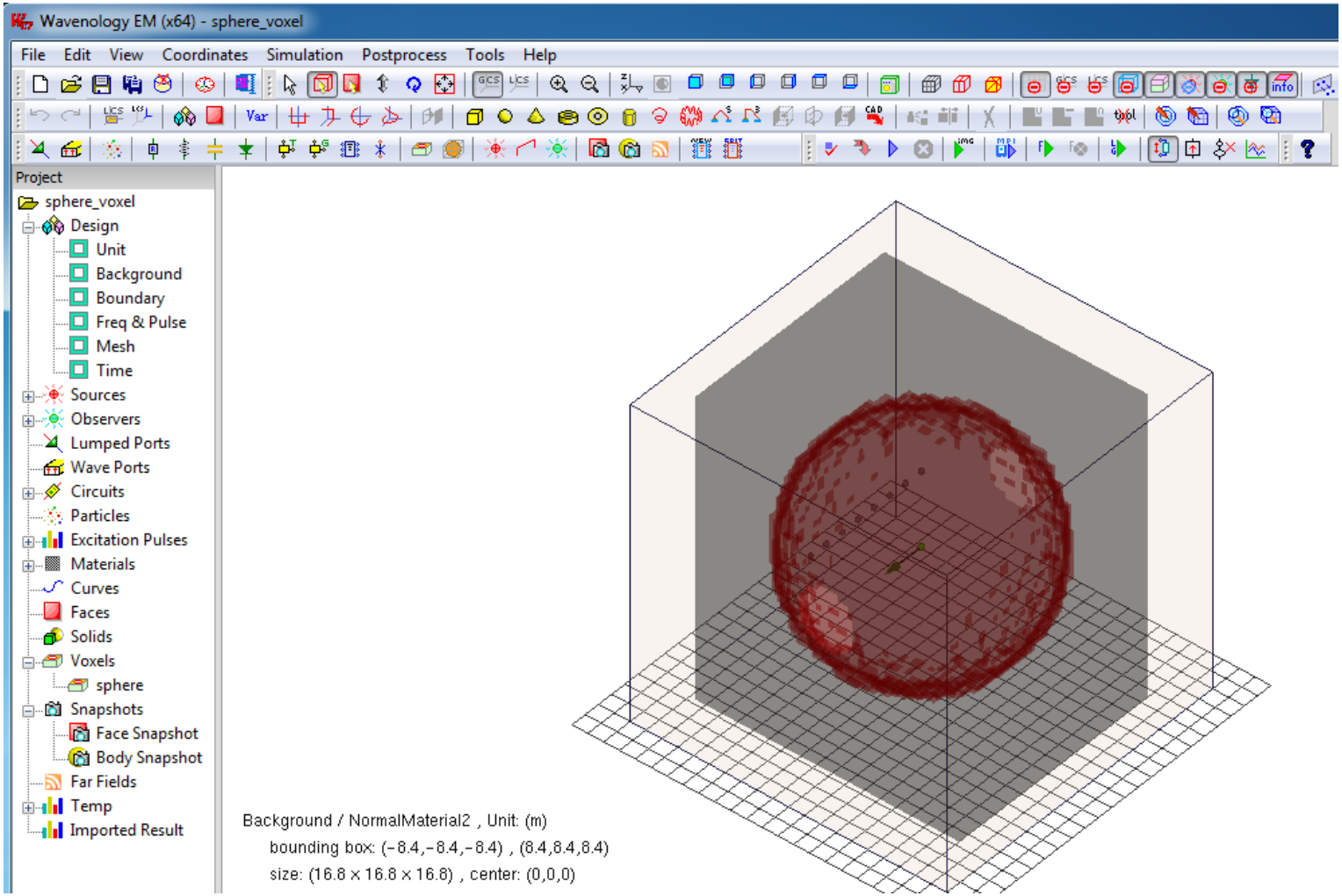
(3)



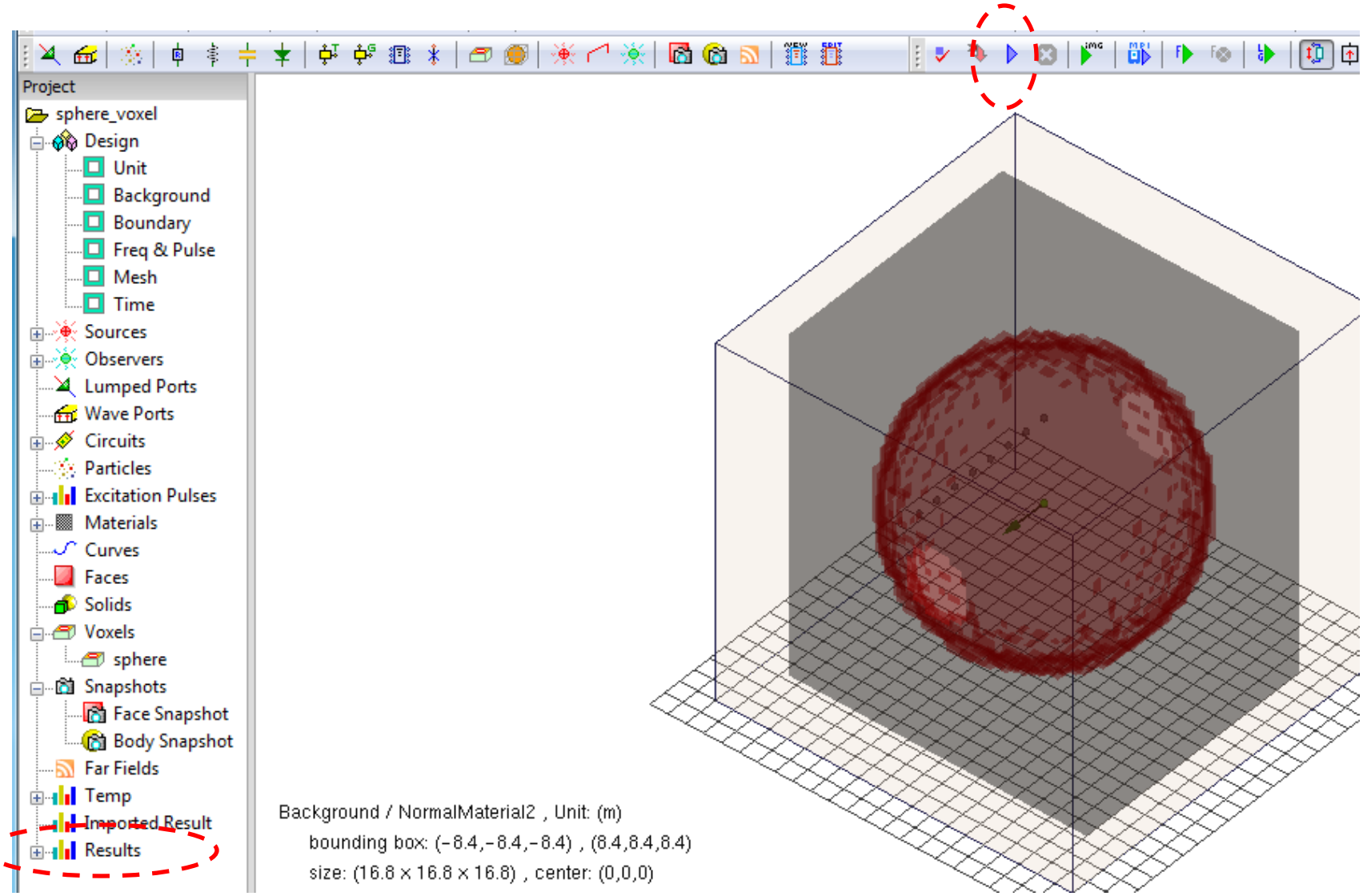
WCT will pre-read part of file to verify the data.

The mesh information is shown here.

7) Press ***OK*** button to finish voxel creation. Then the voxel is shown in 3D canvas.

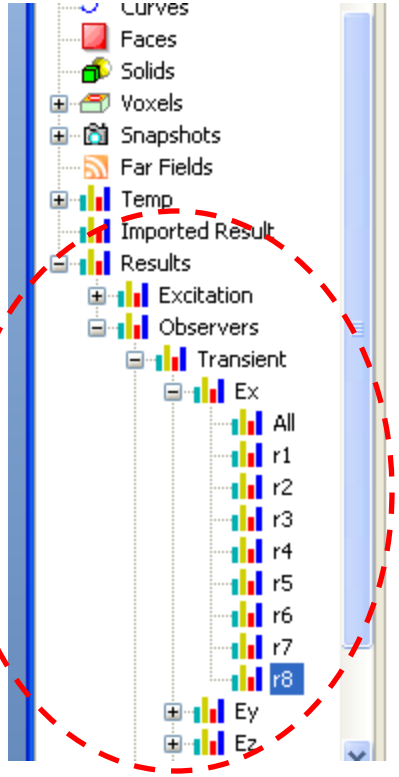


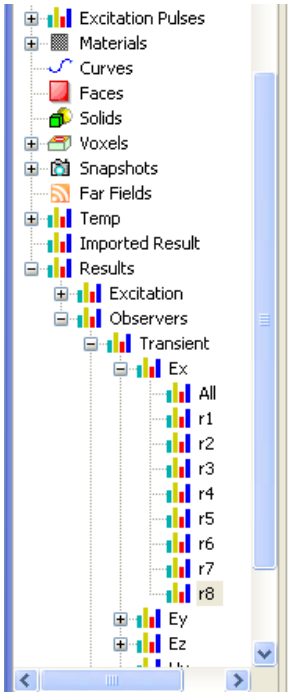
8) Simulate the case and get result.

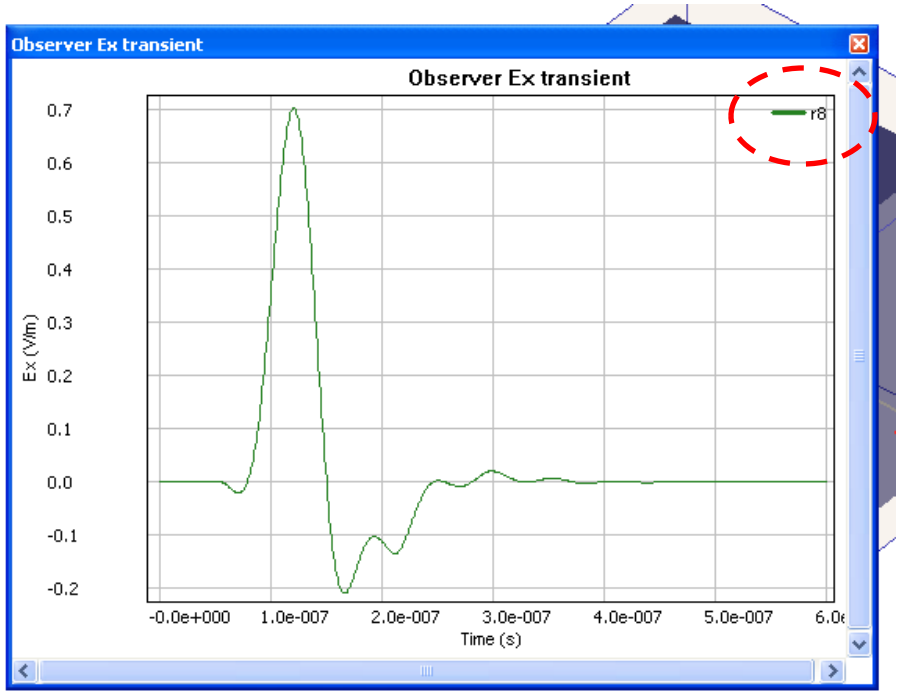


result

9) Compare with Analytical solution

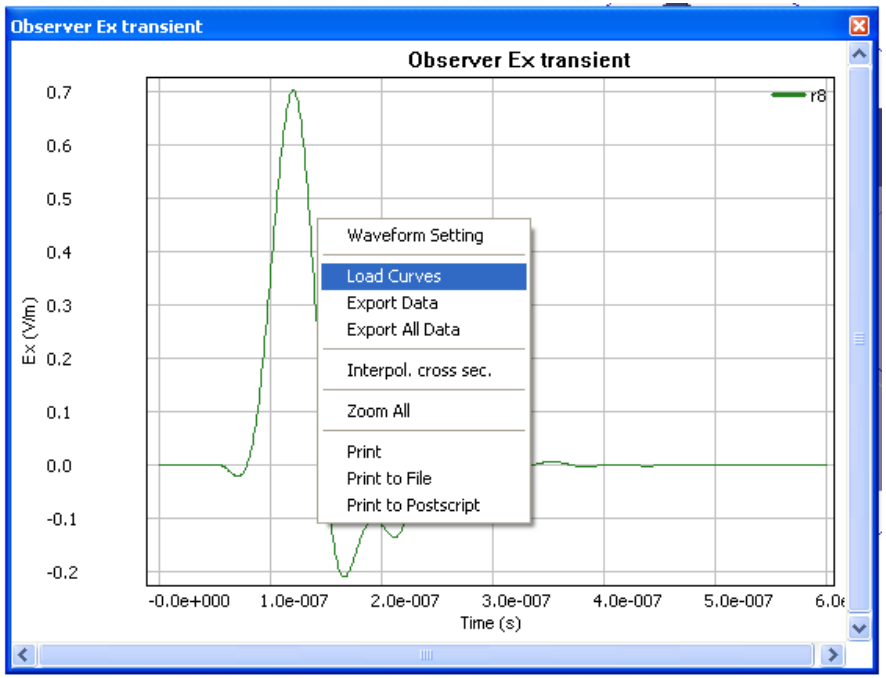


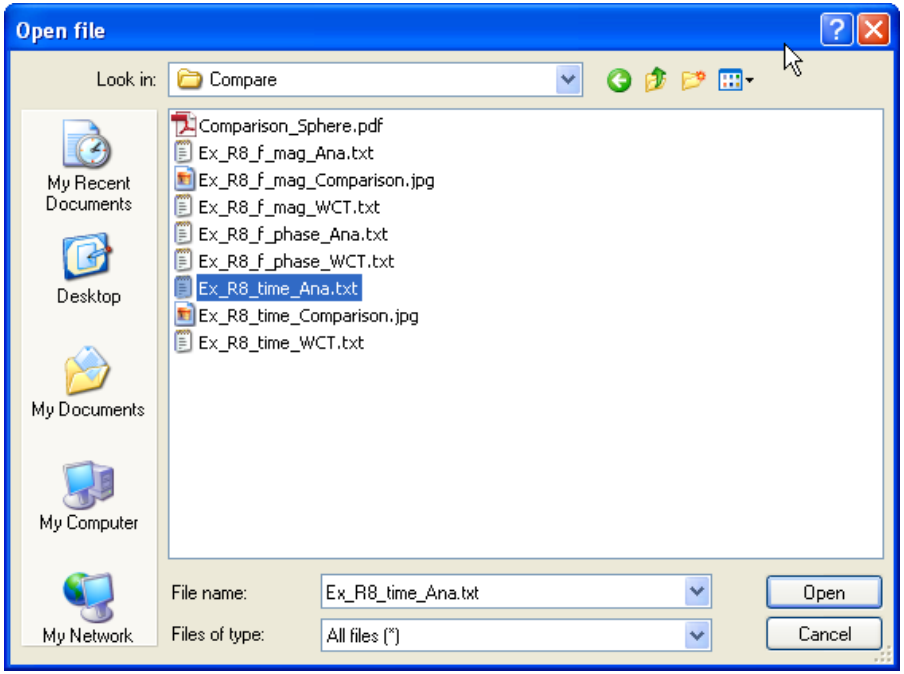


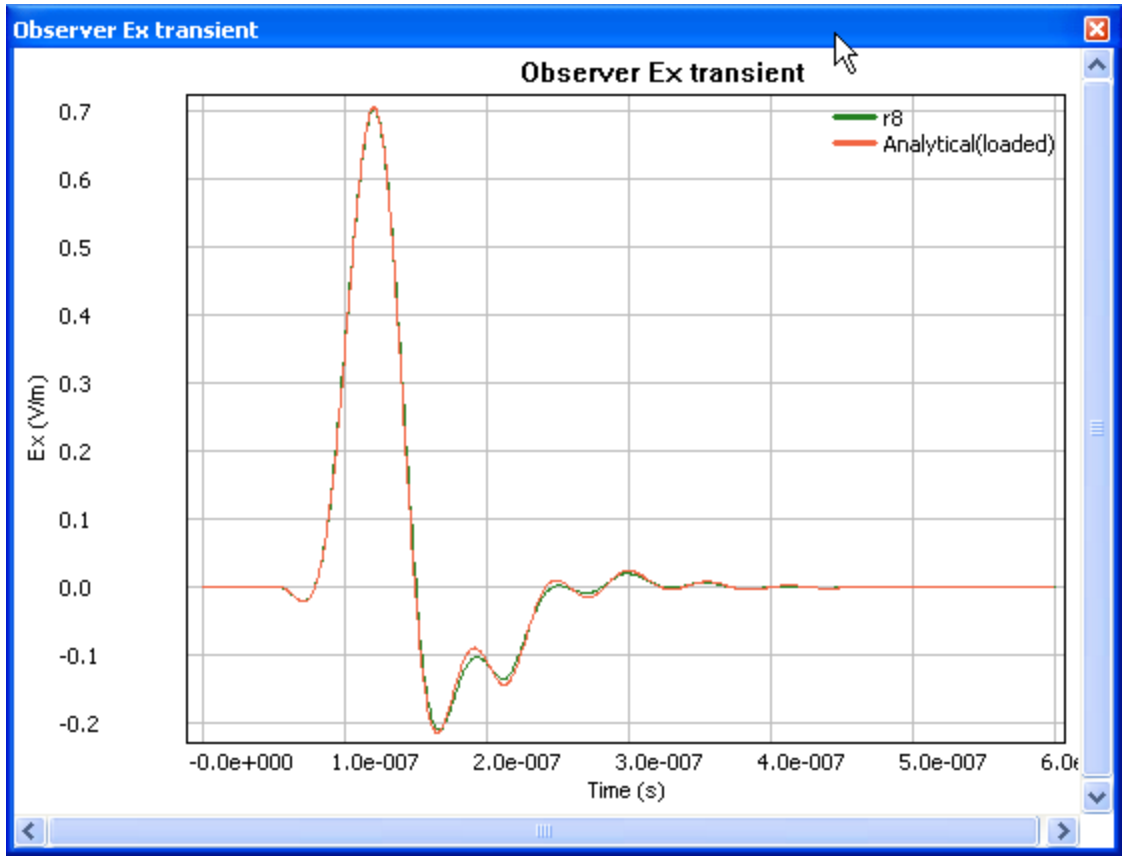


On 2D canvas, ***right*** click the mouse button, get a menu. Click ***Load Curves*** item to load analytical solution.

The analytical solution is under the folder:
\sphere\NormalSphere\Compare\





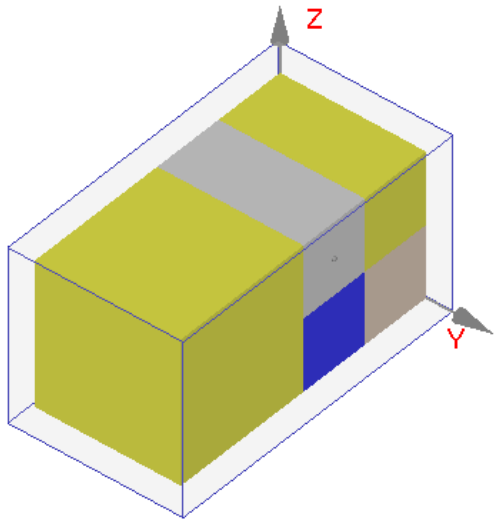


As can be seen, the simulation result is very close to the analytical solution.

The difference comes from the stair casing in discretizing sphere to coarse cubic cell.

Case 2: Multiple Rectangular Solids

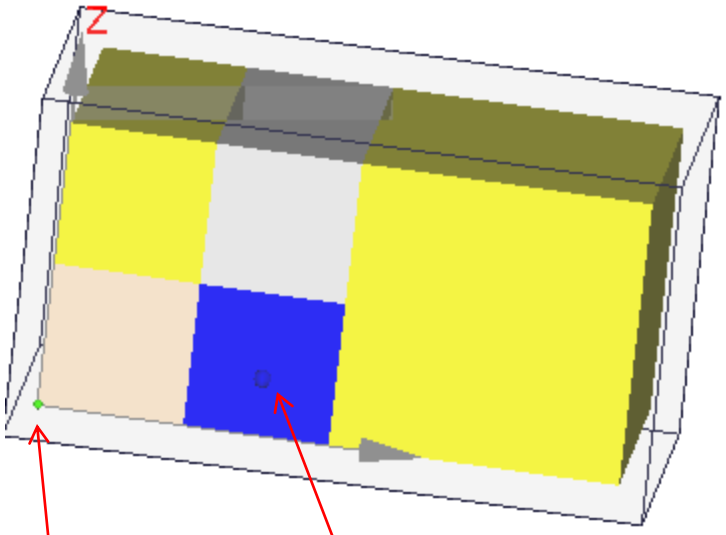
This case demonstrates how to simulate PEC material.



The left Fig. is six solids in homogenous air background, three of them (yellow) are PEC solids

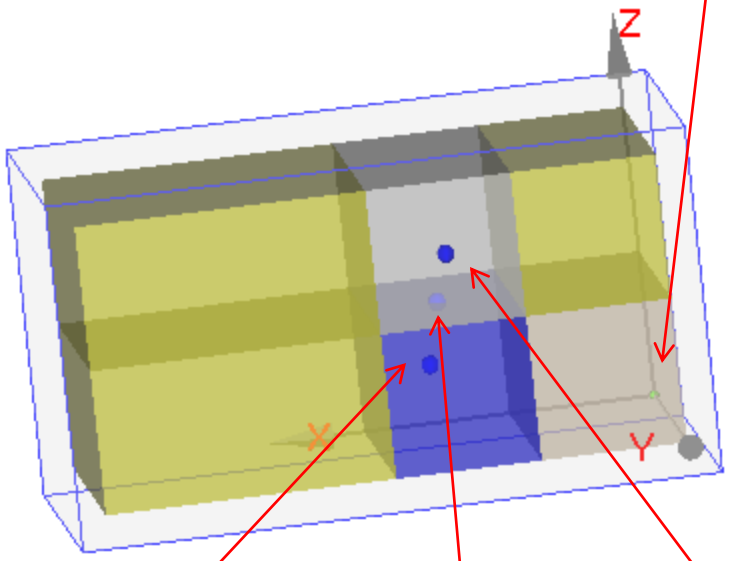
In this voxel case, we will use a voxel to represent these six solids. Because there is not analytical solution for this case. We will compare the result to which comes from six solids case.

Source & Receiver Setup



Ideal E dipole Source

Receiver 1



Ideal E dipole Source

Receiver 1

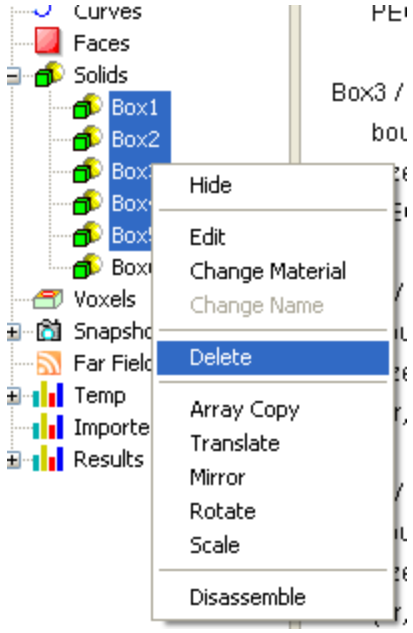
Receiver 2

Receiver 3

Steps:

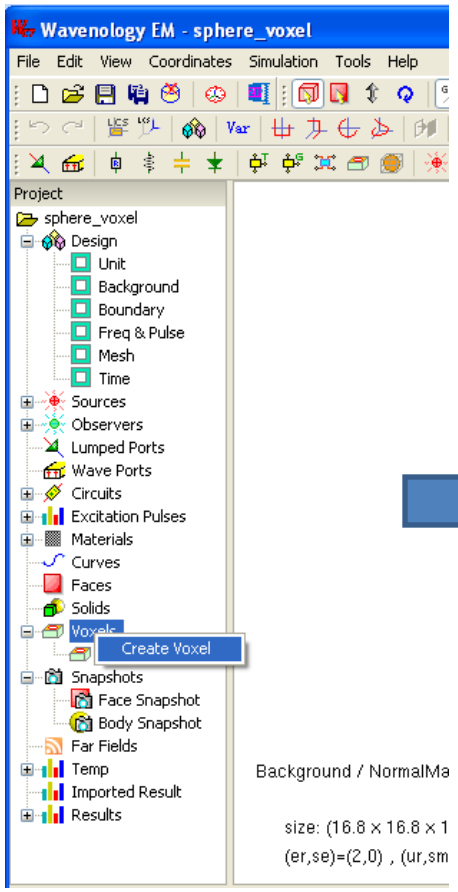
1) Open “\ Boxes\Normal\ Normal.wnt, a project same as the Fig at page 22 can be viewed, **SaveAs** a new case “Voxel”

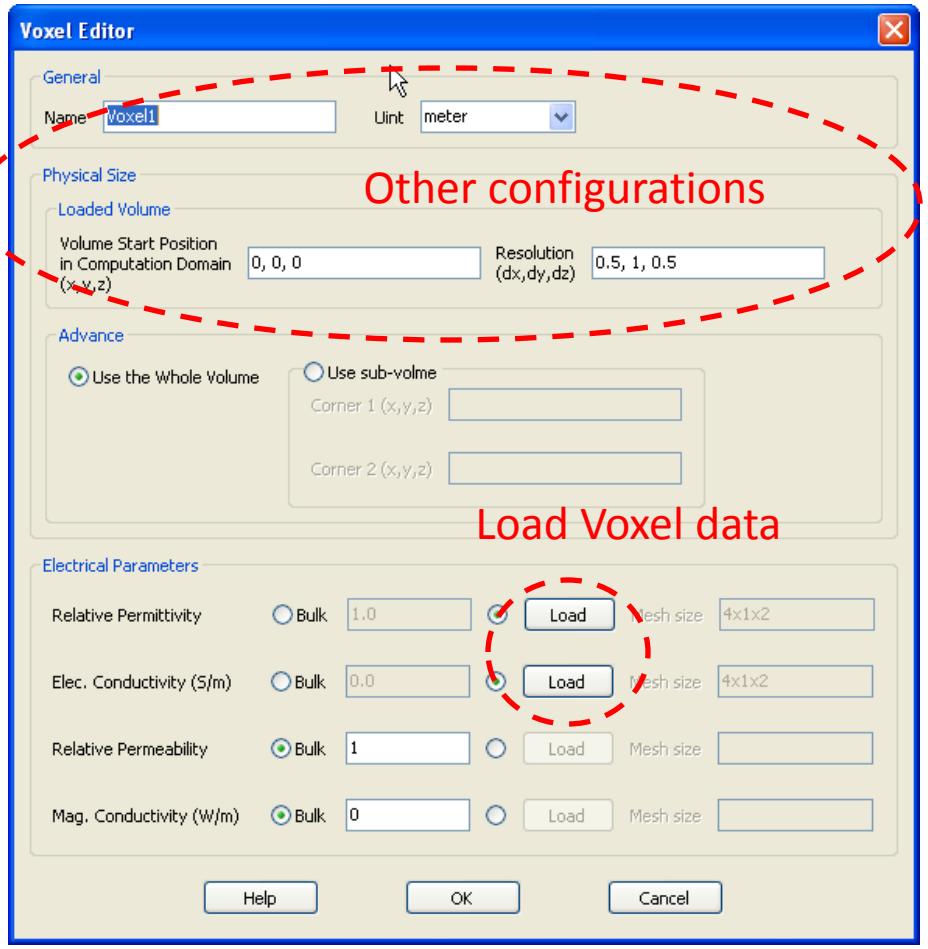
2) Because all B.C. have been set as “OPEN at input position”, here, delete all solids and save



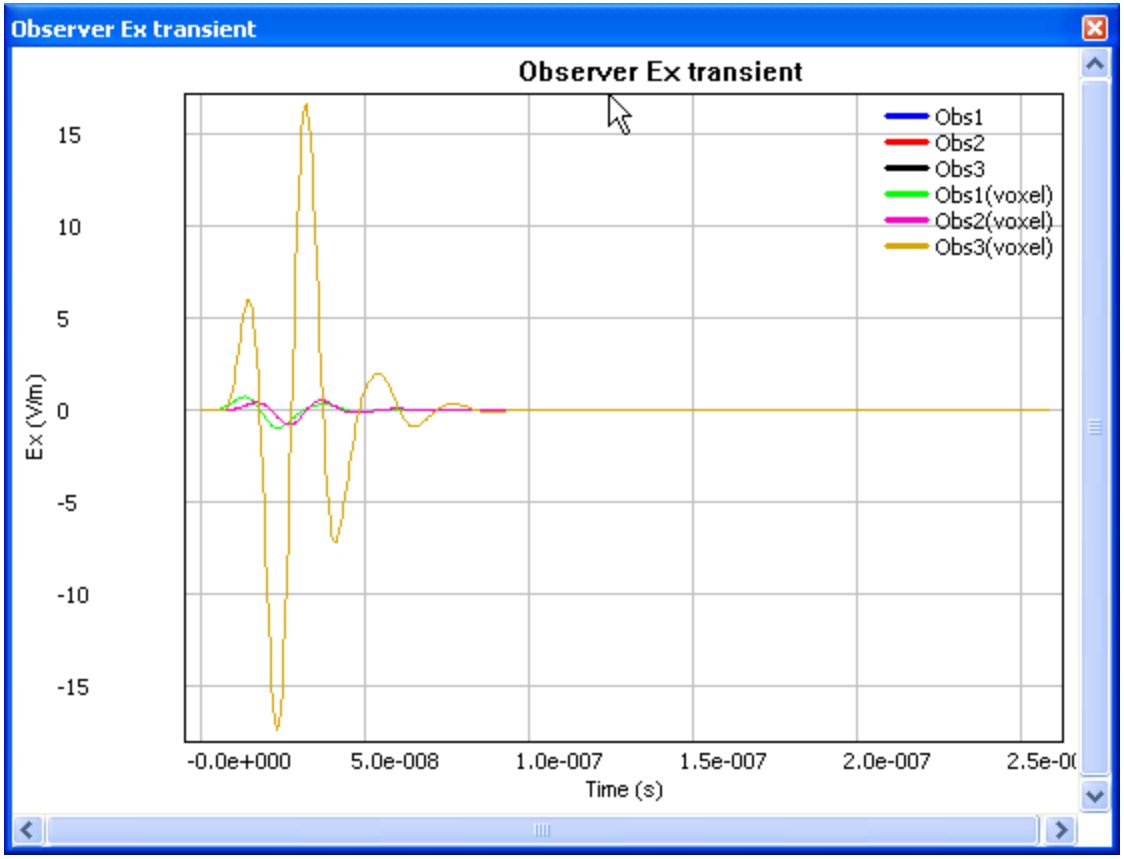
3) Define voxel data files. Because the original solids in this case is rectangular solid, the voxel files is very simple. User can use notepad to create two files as shown in page 9. The resolution of voxel is (0.5, 1, 0.5) m.

4) Define voxel in project.





8) Simulate the case and compare result.



As can be seen, the results from voxel simulation match that from the simulation with six solids

Case 3: Simulation on A Digital Breast Model

The digital breast model is obtained from:

UWCEM Numerical Breast Phantoms Repository, http://uwcem.ece.wisc.edu/MRIdatabase/.

The manual of the database is "Database of 3D Grid-Based Numerical Breast Phantoms for use in Computational Electromagnetics Simulations: http://uwcem.ece.wisc.edu/MRIdatabase/InstructionManual.pdf.

There are four models in this repository, corresponding to four categories of breast (the American College of Radiology categories).

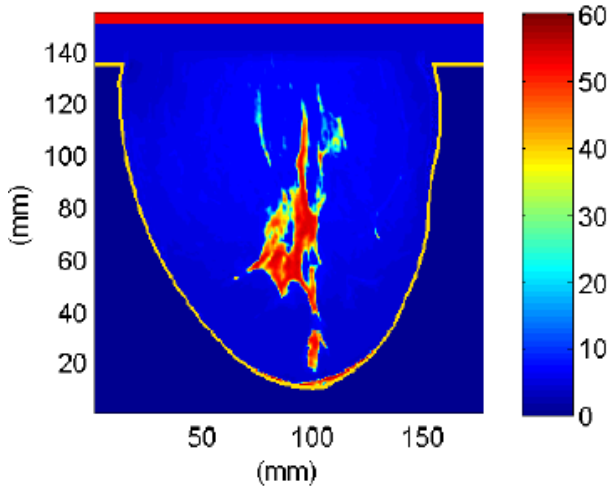
In this case, we use model "ACR CLASS 1 - Mostly Fatty, Phantom 1". The original model is MRI contrast data, we use "MRI contrast-EM profile conversion" method to obtain the ε_r & σ_e. Please refer to following papers to get the conversion method:

1) M. Lazebnik, S. C. Hagne, "A large-scale study of the ultrawide band microwave dielectric properties of normal breast tissue obtained from reduction surgeries," Phys. Med. Biol., vol. 52, pp. 2637-2656, 2007.

2) M. Lazebnik, S. C. Hagness, "A large-scale study of the ultrawideband microwave dielectric properties of normal, benign, and malignant breast tissues obtained from cancer surgeries," Phys. Med. Biol., vol. 52, pp. 6093-6115, Oct. 2007.

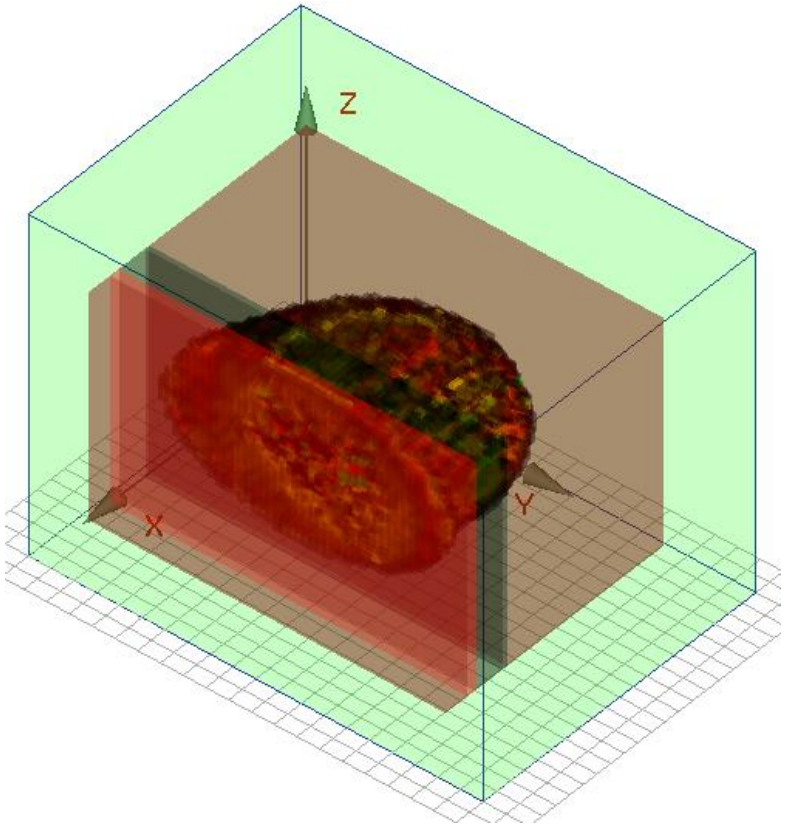
Due to the high resolution of original model, and the for-loop is different from WCT voxel definition. We down sample this model to a resolution of 1.5x1.5x1.5 mm^3; and convert data sequence as *for x:y:z loop*.

The final data file in WCT voxel format is *breast_eps.vxb* & *breast_econd.vxb.*



One cross-section of the converted model is shown in left Fig.

The loaded 3D breast model in the GUI looks like

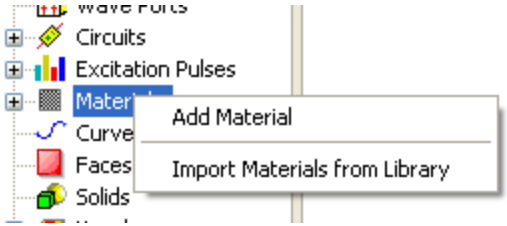


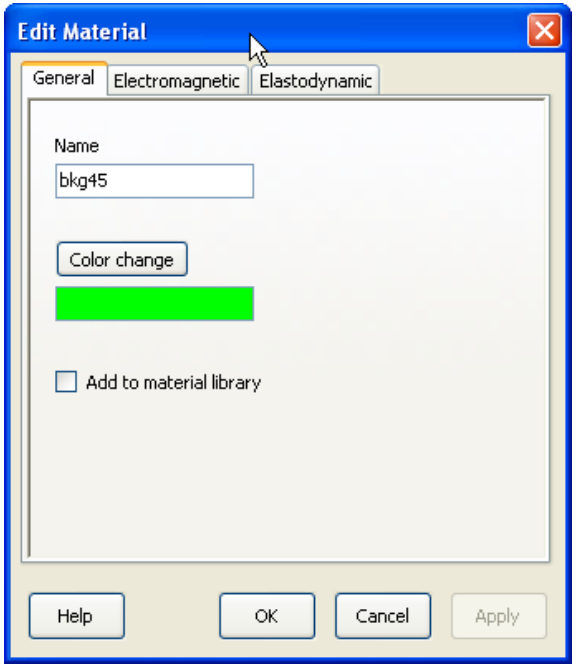
The size of the voxel volume is 12x16.5x10.5 cm^3, with 80x110x70 cells in x, y and z direction, respectively.
For this model, the material outside the breast has $\varepsilon_r = 4.5$, $\sigma_e = 0$.

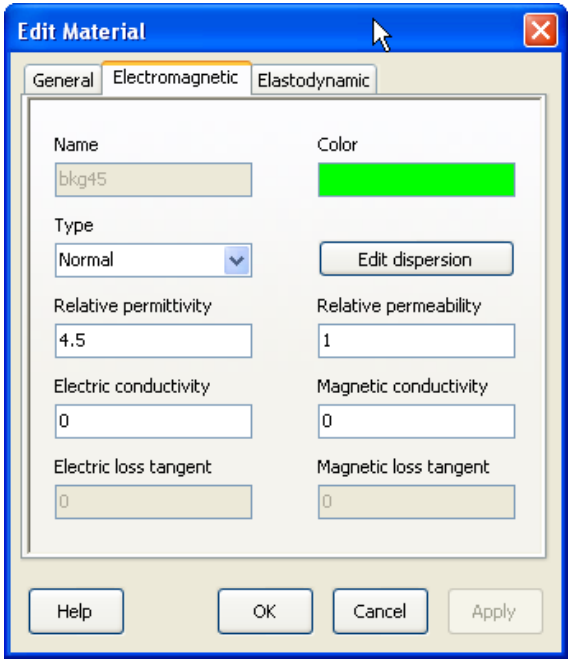
In this case, we will show how to use face-snapshot to monitor the propagation of EM wave in the breast. The source is an ideal E dipole outside the breast model. The breast model is immersed into a matching material with ε_r =4.5, σ_e=0 to reduce the reflection from the breast.

Steps:

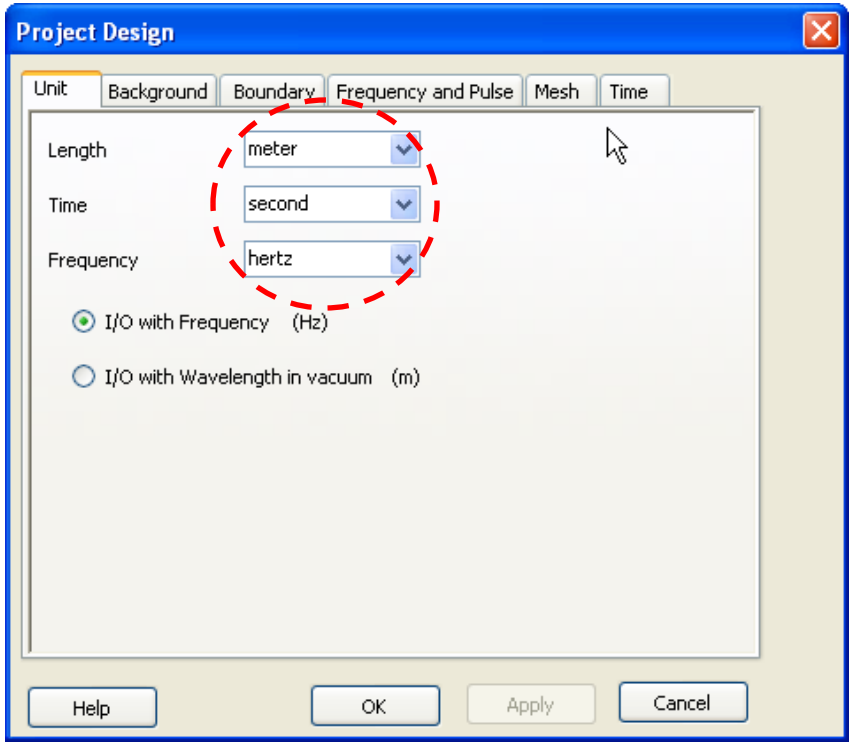
(1) Create a new case and save with name “tpl”
(2) Create matching material “bkg45”

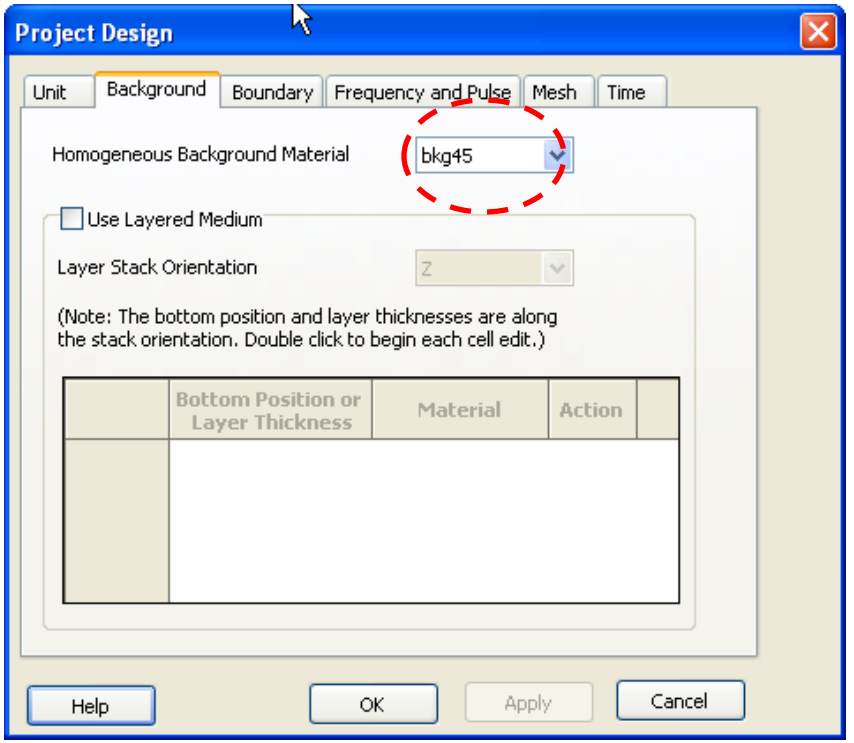




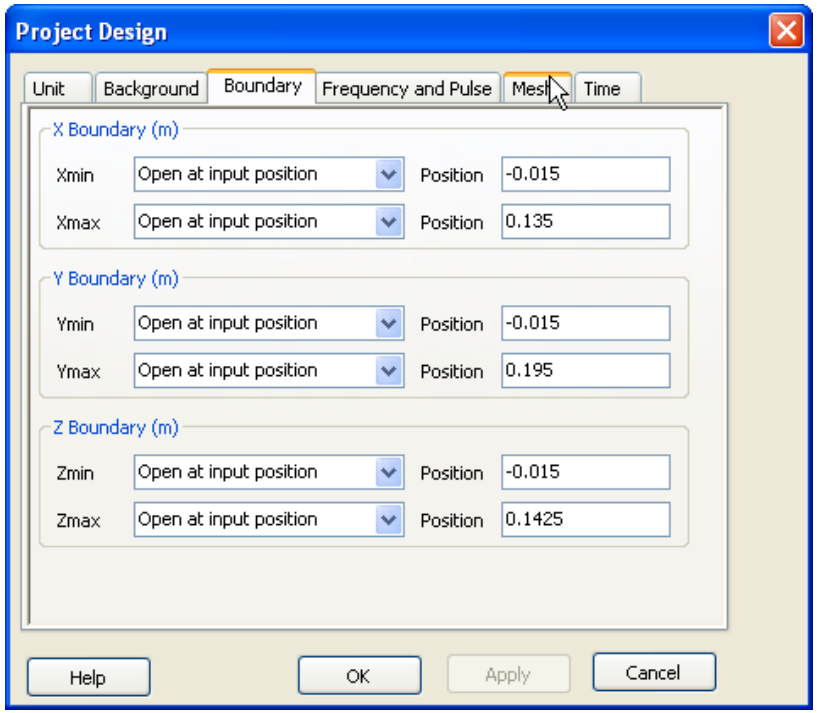


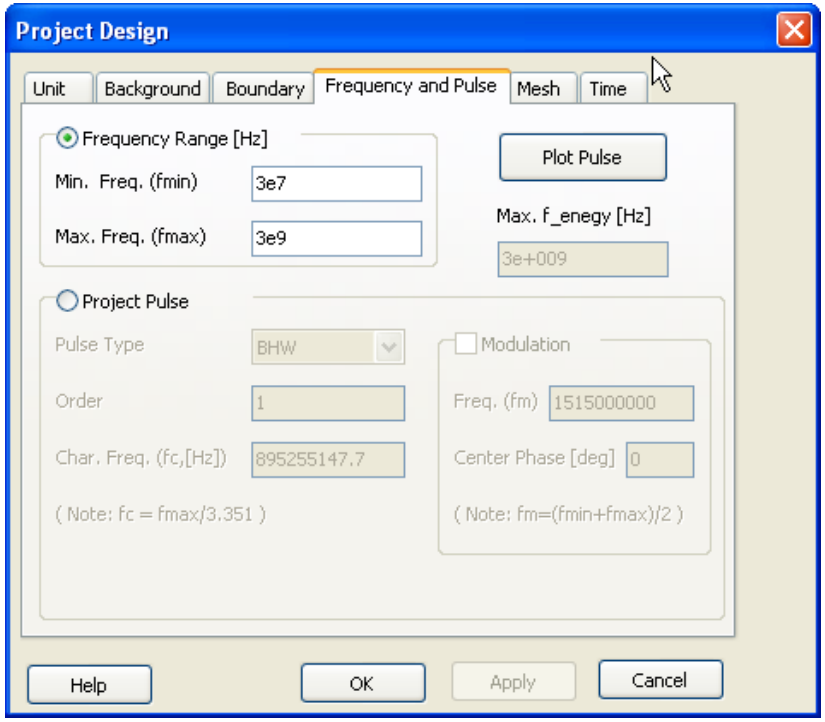
(3) Setup project unit as **meter, second & hertz**, background as "Bkg45".



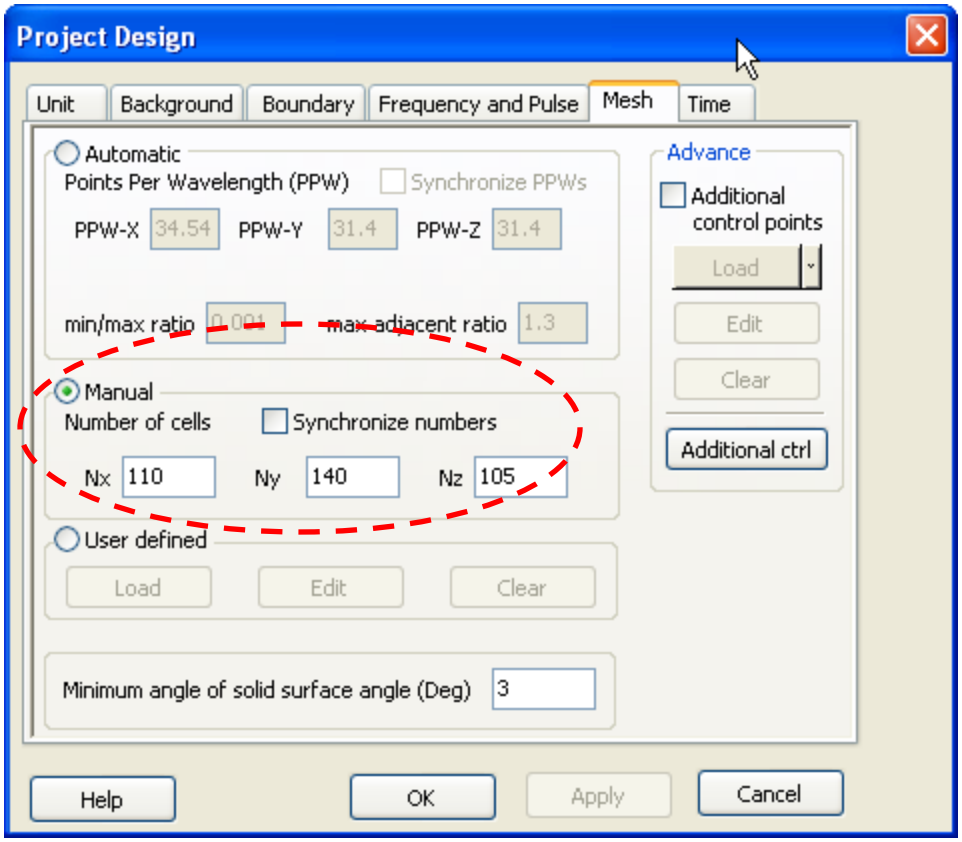


set computation domain B.C. as following, and set simulation frequency as $3e^7$-$3e^9$ Hz

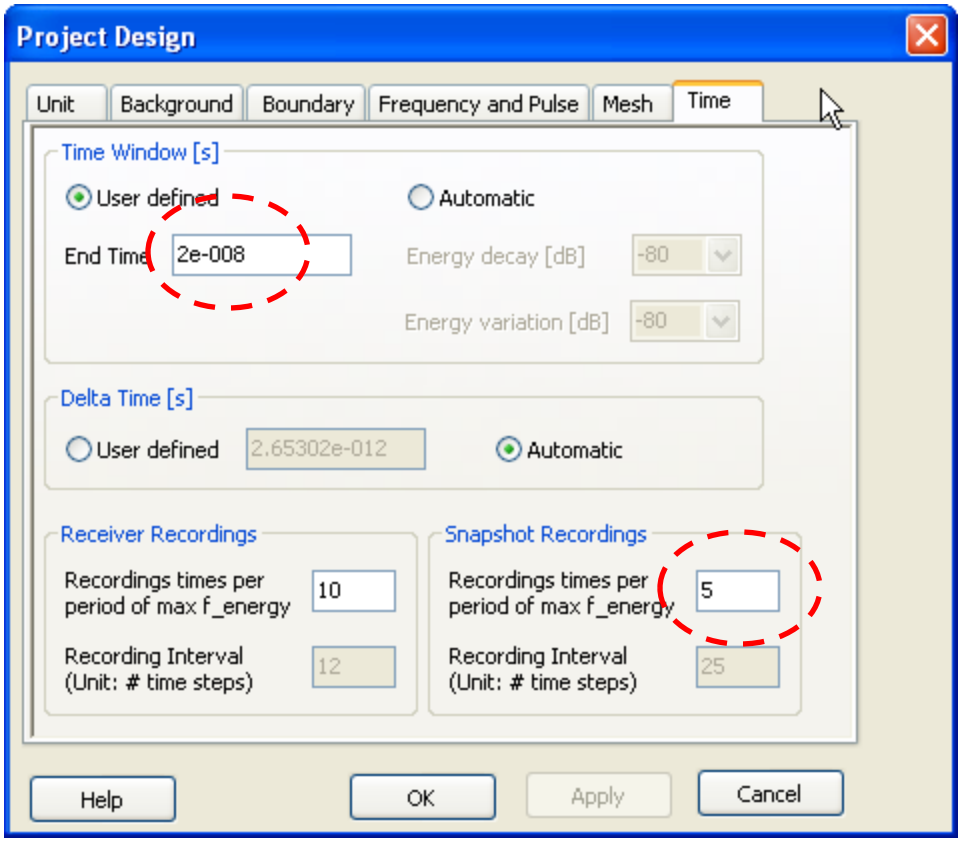




Because we want to capture the signal in all voxel cell, we use manual uniform mesh as following. (user can use **Automatic** mesh also)

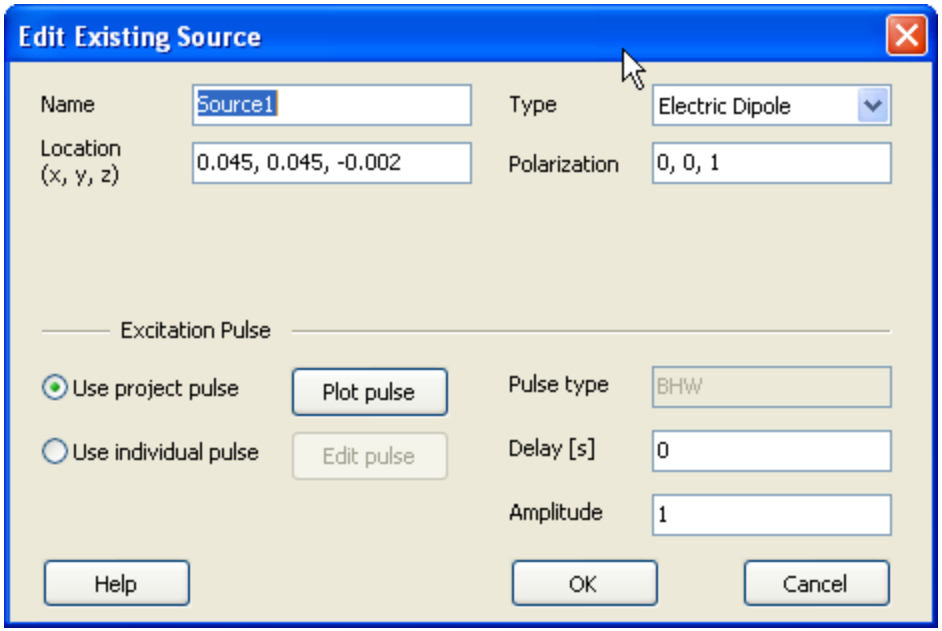


Because we only want to capture the transient signal on face-snapshot, we don't need to analyze the frequency response. Here, we use "**User defined**" time window, 8 *ns*.

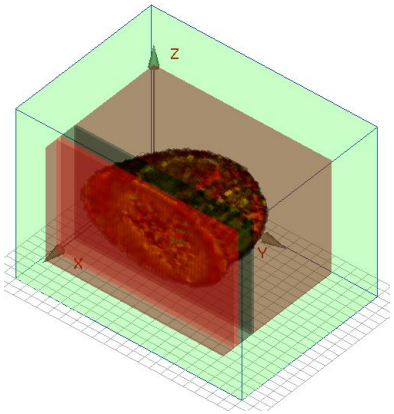


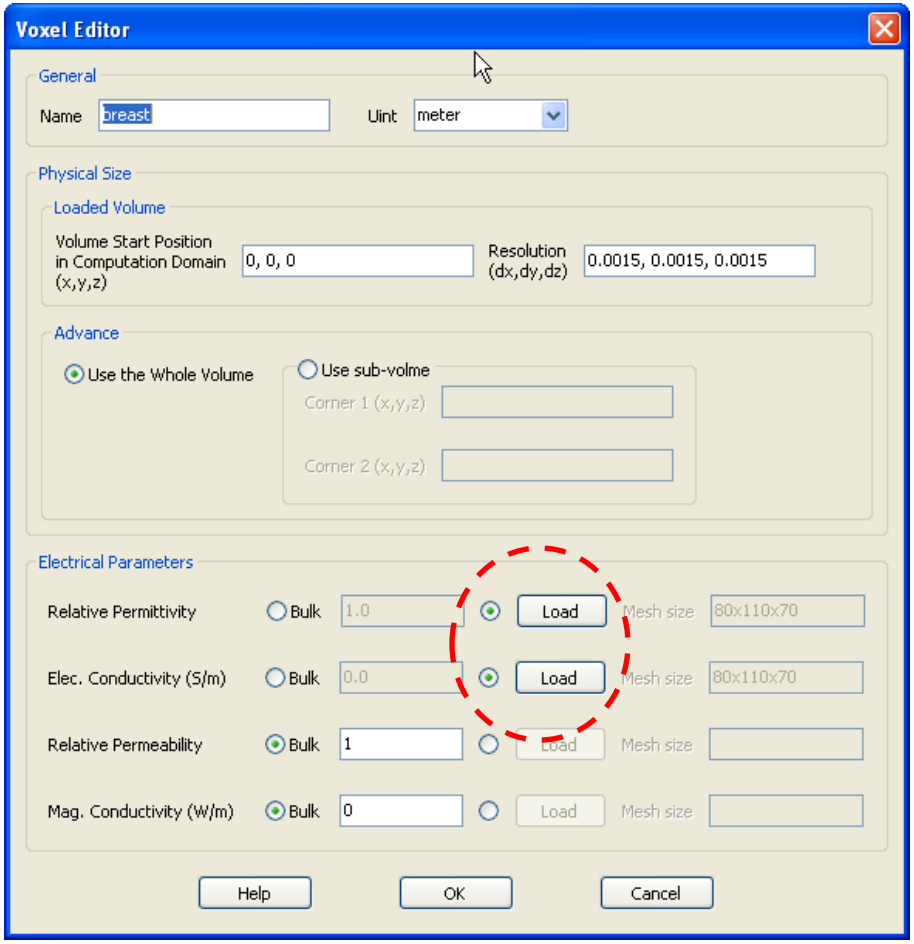
In order to make the picture on the snapshot more smooth, we increase "Snapshot Recordings" density to 5 points per wavelength at f_{max} ($3e^9$Hz) .

4) Add dipole source in the project.



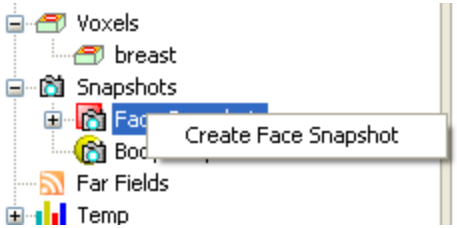
5) Define voxel

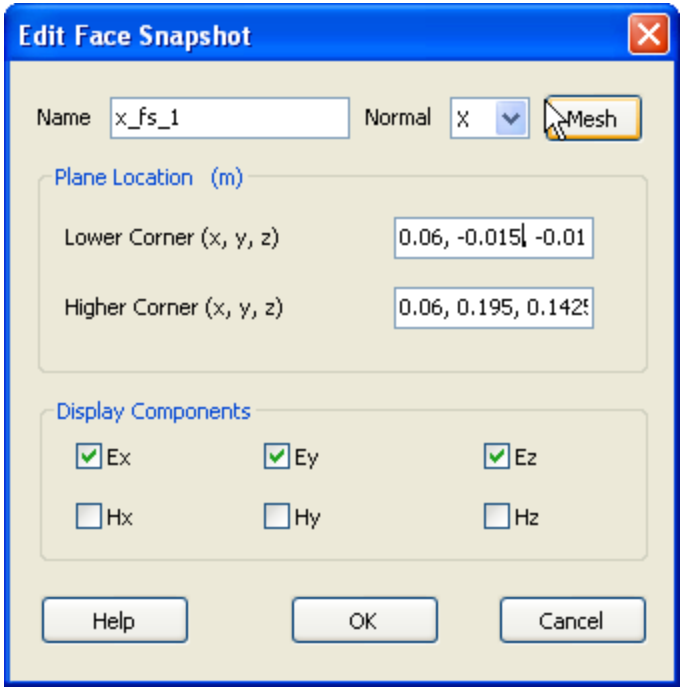




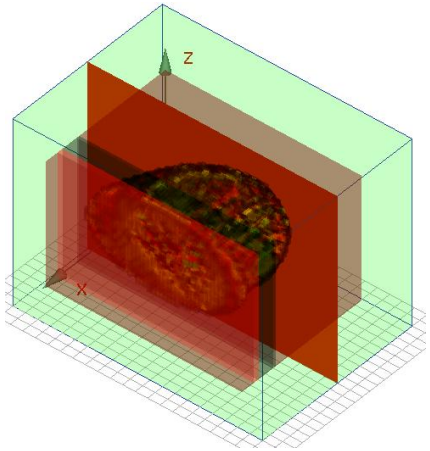
The data file is breast_eps.vxb & *breast_econd.vxb* under folder *Digital_breast_model.*

5) Define face-snapshots

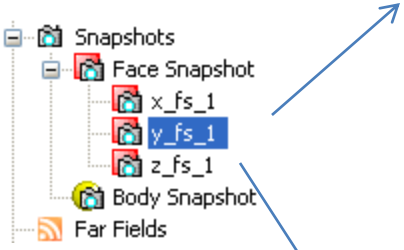


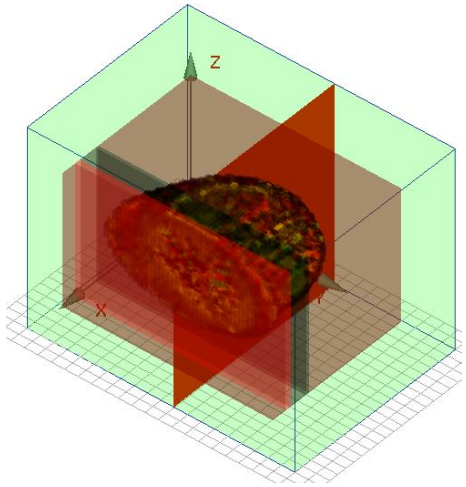


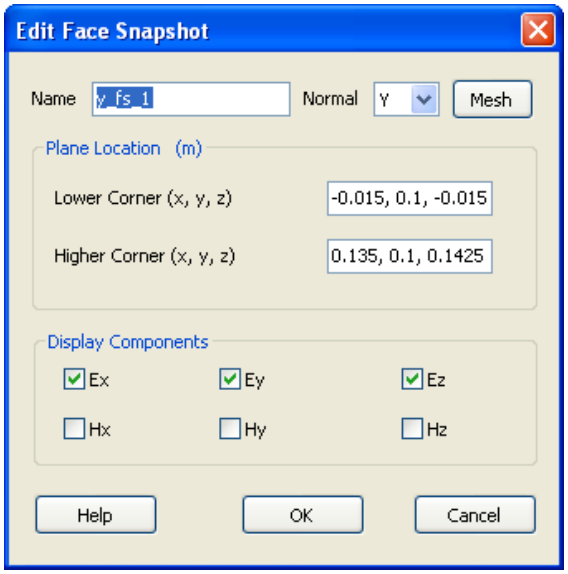
X normal snapshot,
capture E field only

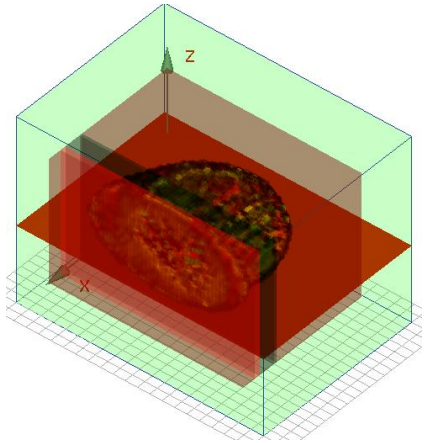


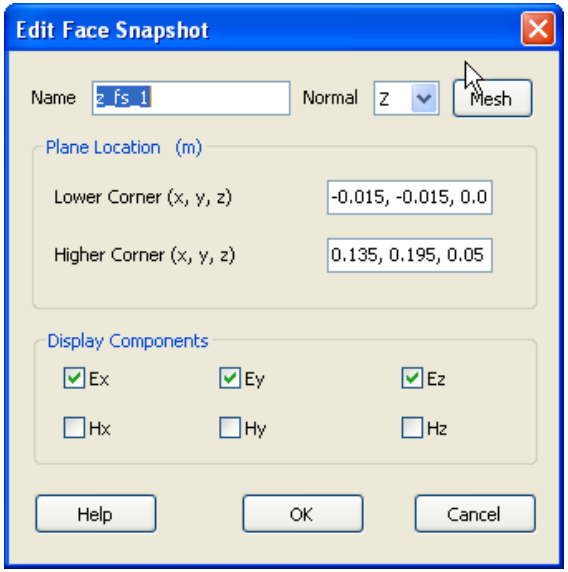
Y normal snapshot







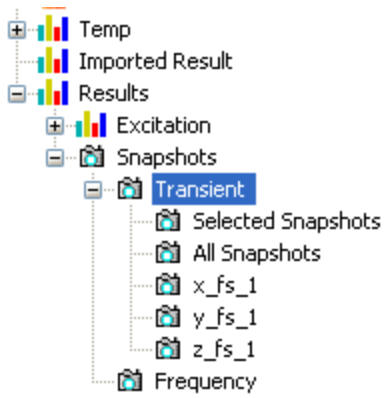




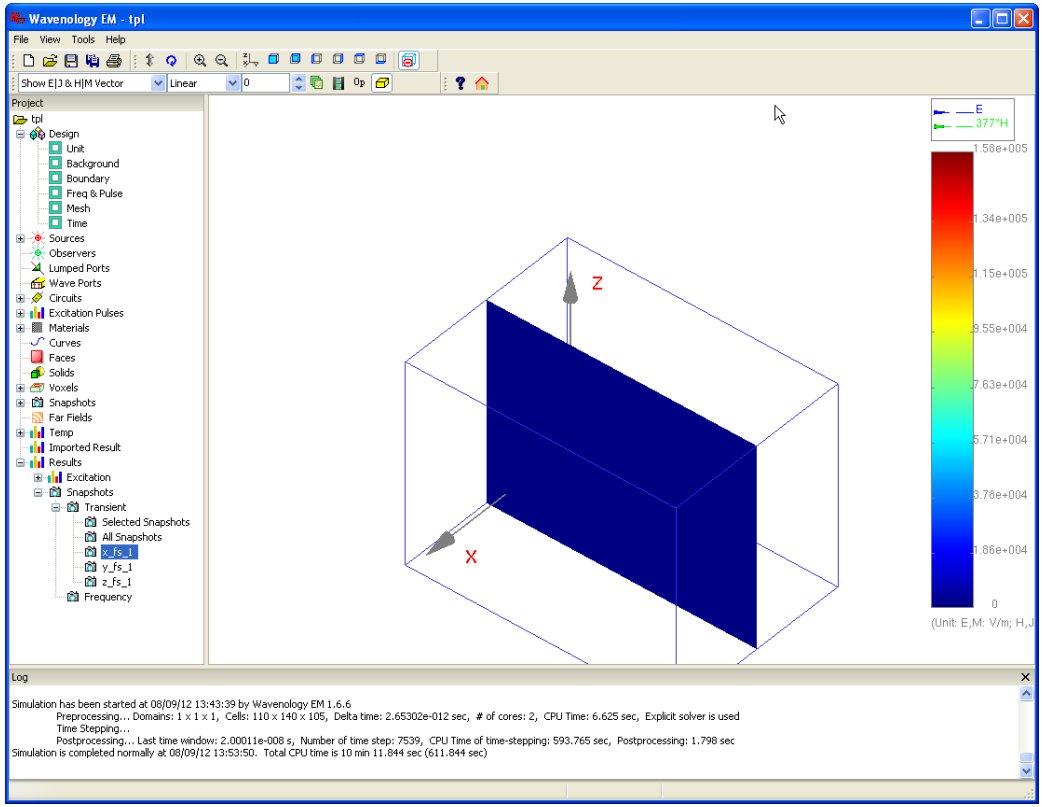
Z normal snapshot

6) Simulate the case and check result.

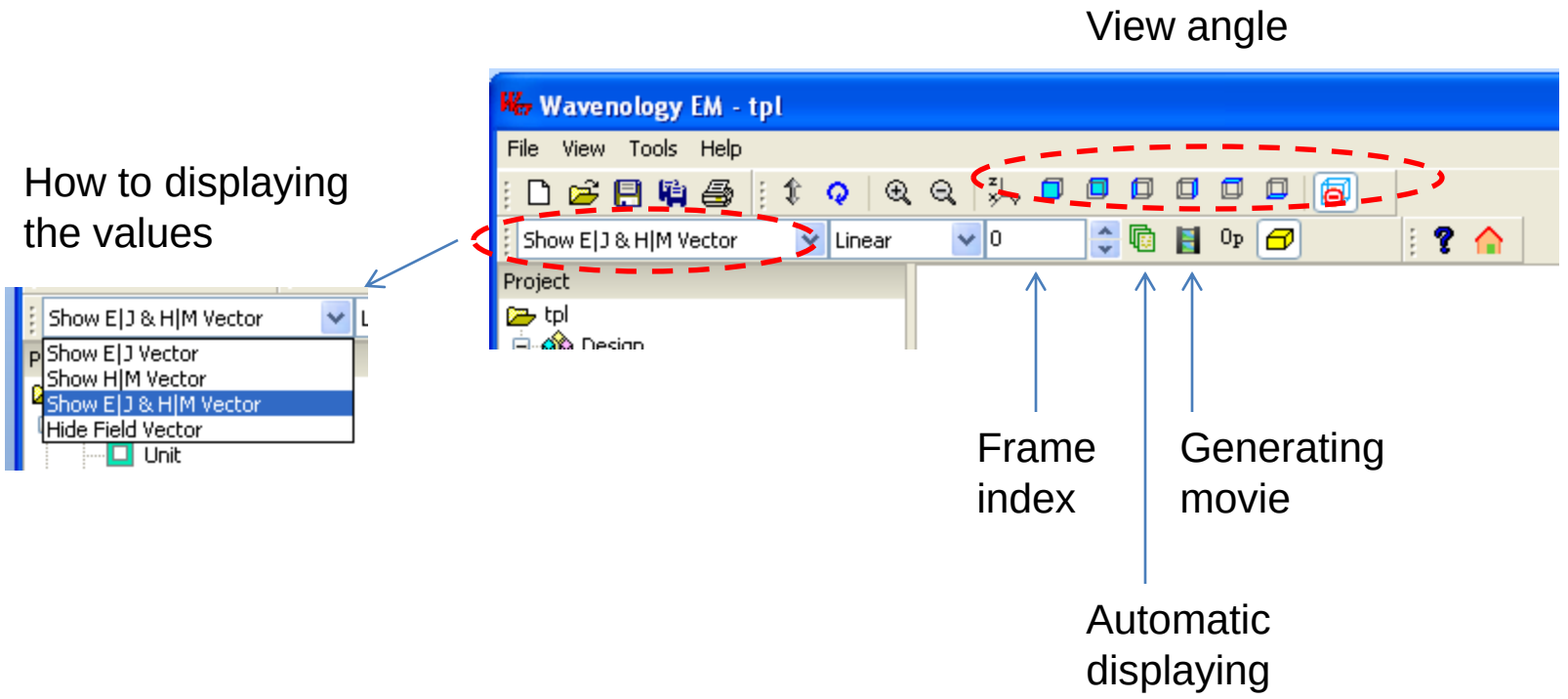
Expand Results treenode till you can see ***Snapshot*** -> ***Transient***



Click “x_fs_1” snapshot to enter snapshot displaying mode

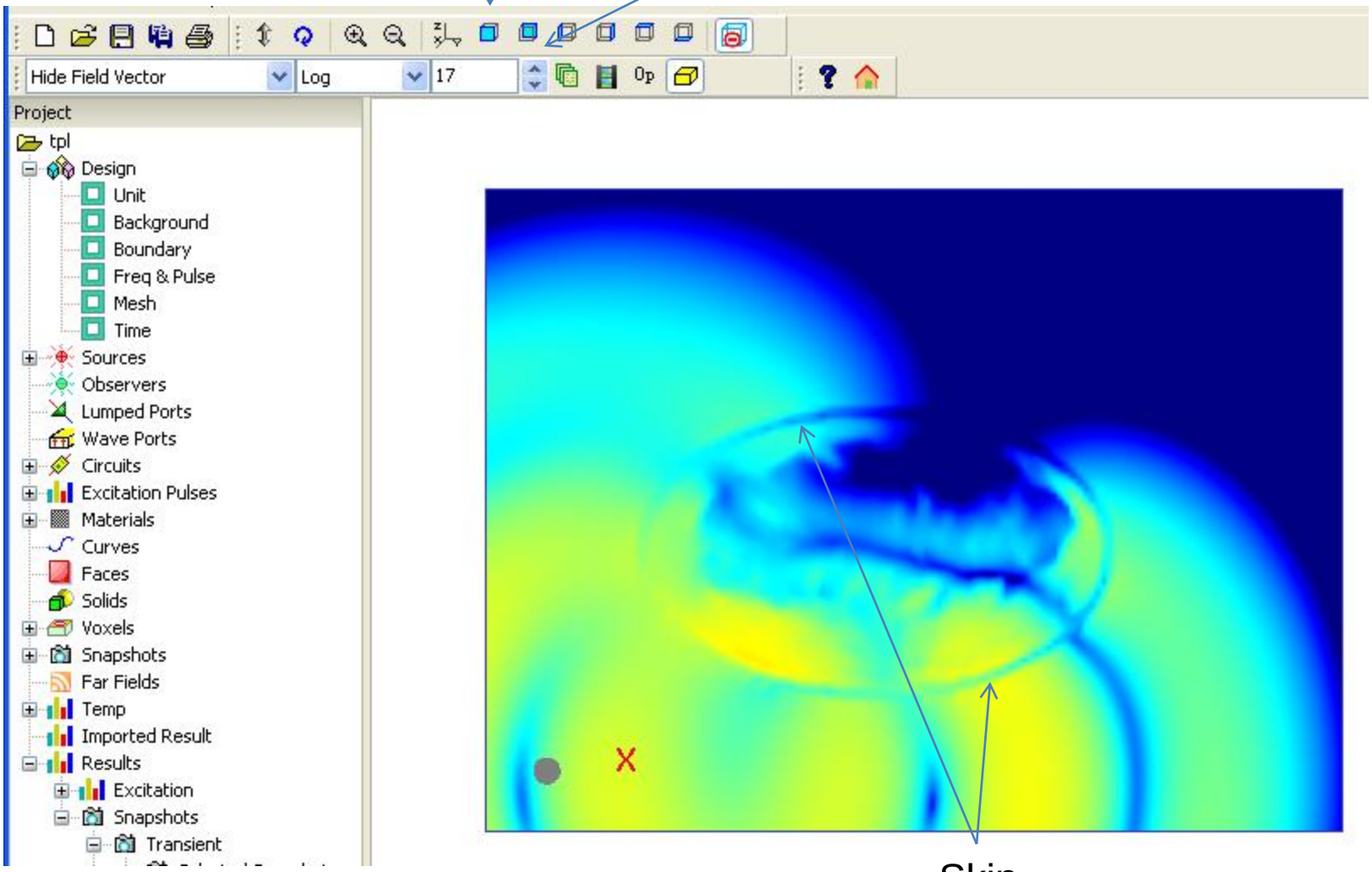


User can user this toolbar to control the snapshot displaying

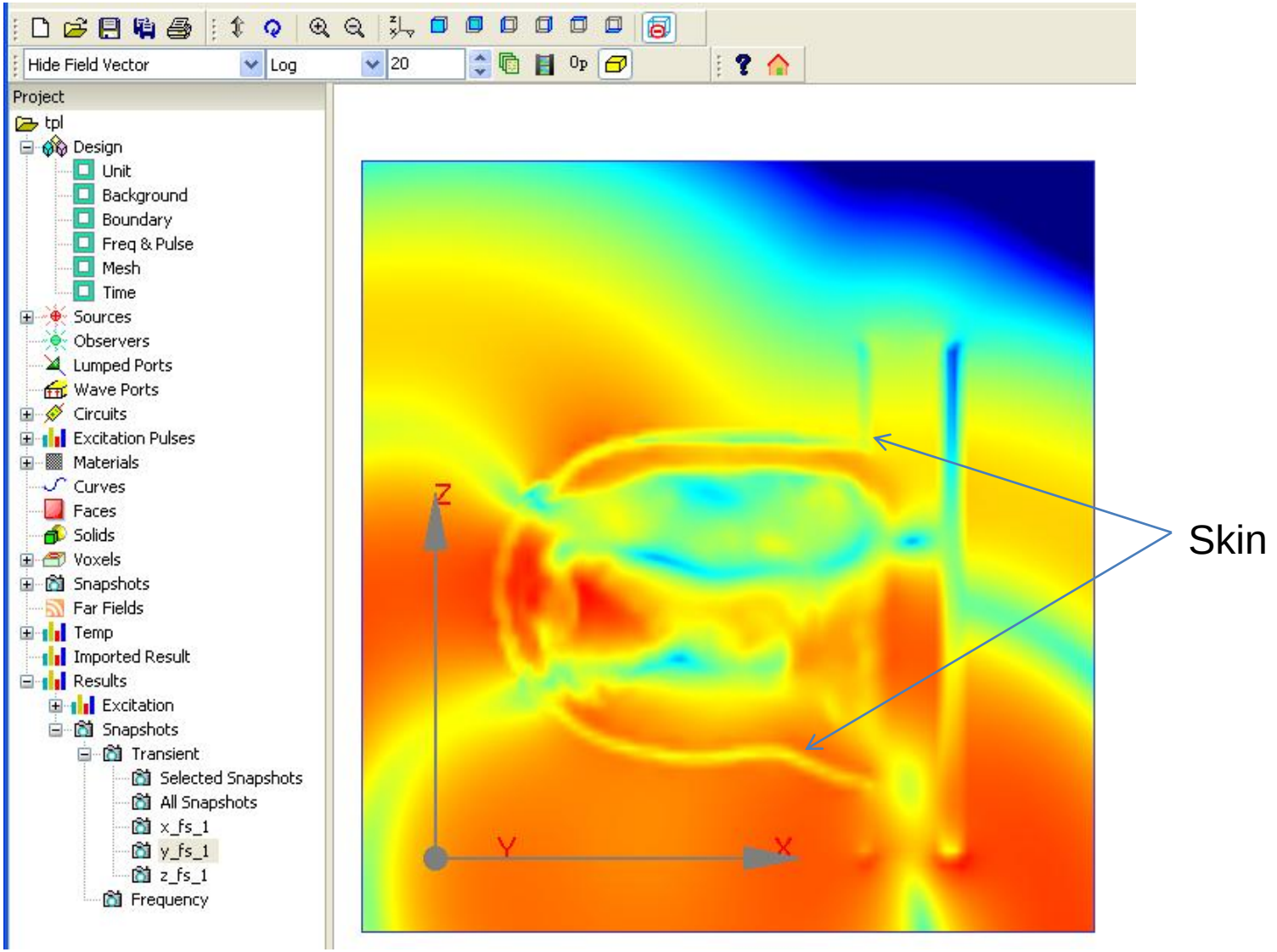


Here, we choose “front view” + “Hide Field Vector” + “Log” mode

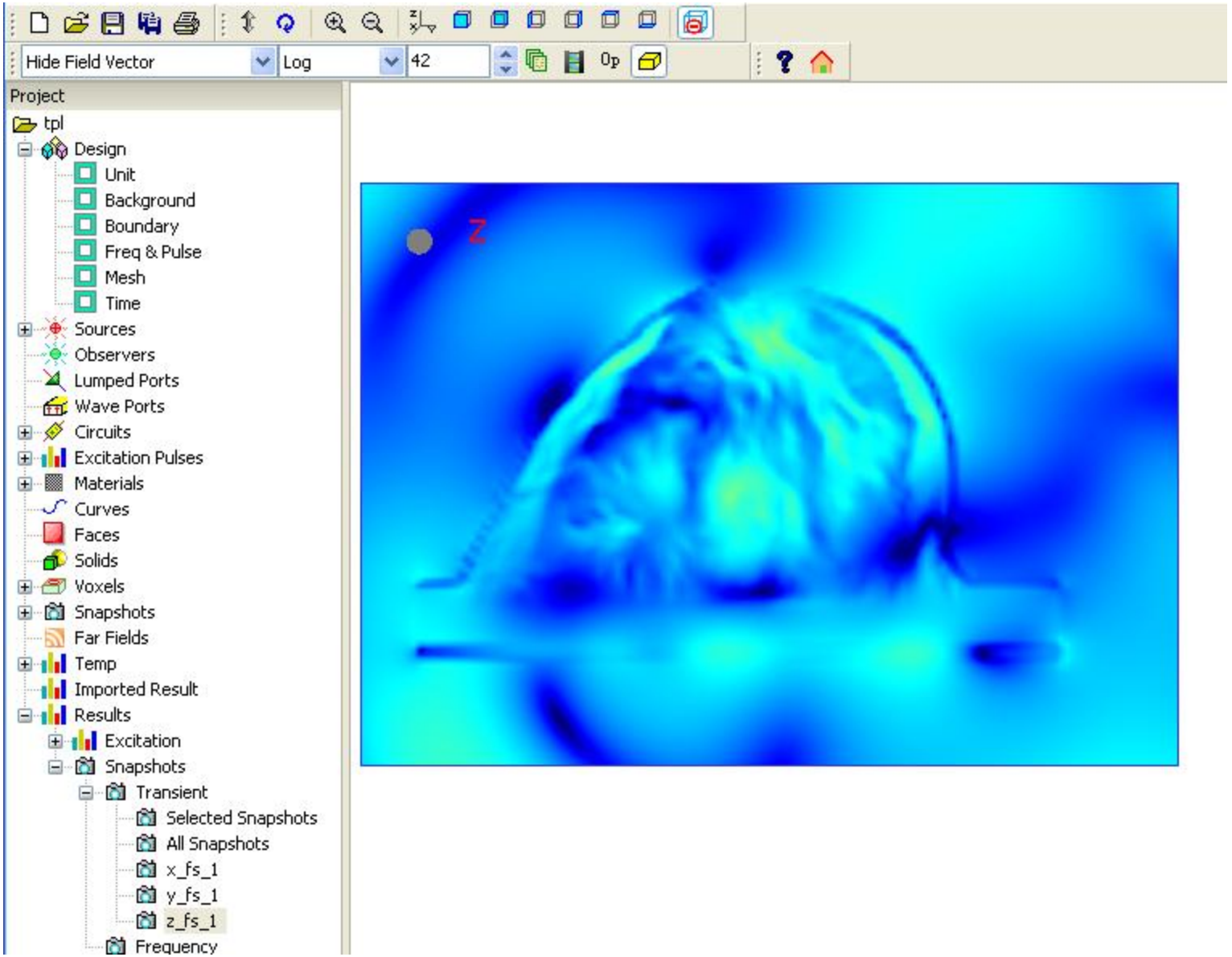
then use the spin button to change displayed frame index. The E field propagation around breast can be observed clearly.



Similarly, for y plane snapshot “y_sf_1”, we choose “left view” + “Hide Field Vector” + “Log” mode to display



Similarly, for z plane snapshot “z_sf_1”, we choose “top view” + “Hide Field Vector” + “Log” mode to display



Voxel Demo Cases

Part II: EL Solver

1) Transient response from a Box in 3layered background, general isotropic material

2) Transient response from a Box in homogenous background, weak anisotropic material

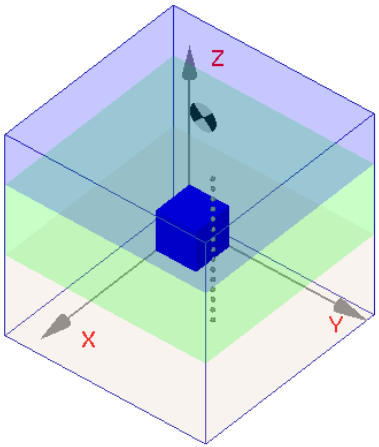
3) Simulation on 2D Marmousi II model

4) Simulation on SEG_EAGE_3DOverThrustModel

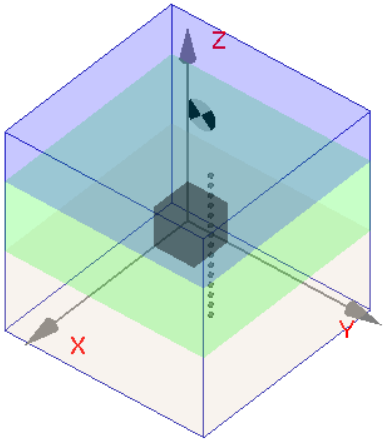
Case (1) a Box in 3 layers Background

general isotropic material

This case simulates a box in a 3 layers background. We will show how to define this box by the voxel way and compare the simulation result with the result by defining a box by a normal way.



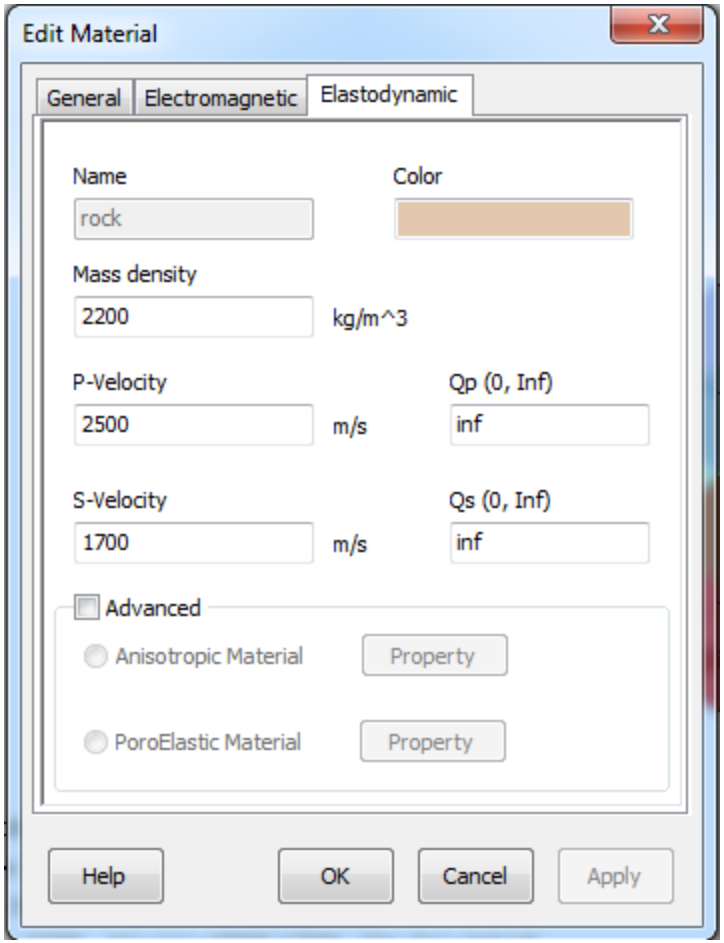
The left Fig. is the reference case, a regular box in a 3 layers background.



In the voxel case, we will replace the box region by a voxel with 2x2x2 cells, and tehn compare the transient response on receiver in two cases.

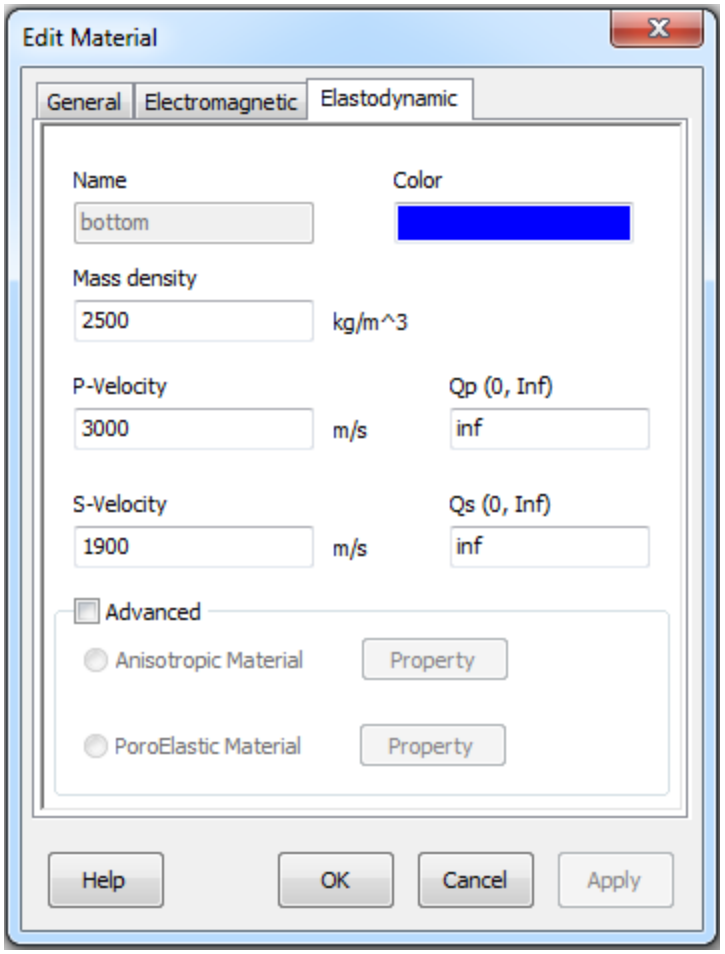
Case setup: Materials

Rock



for top layer

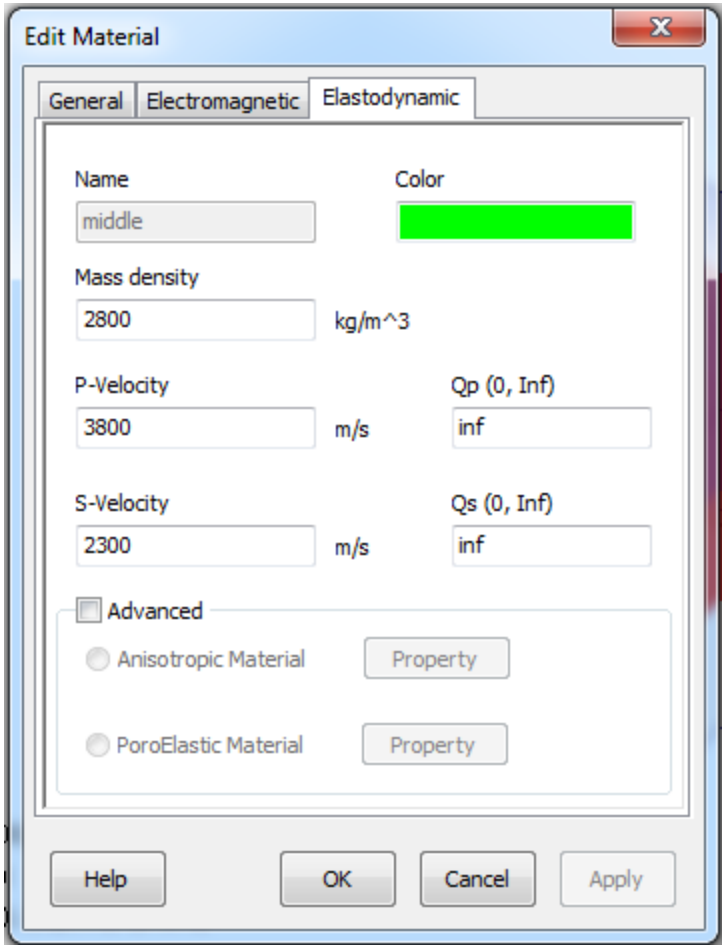
Bottom

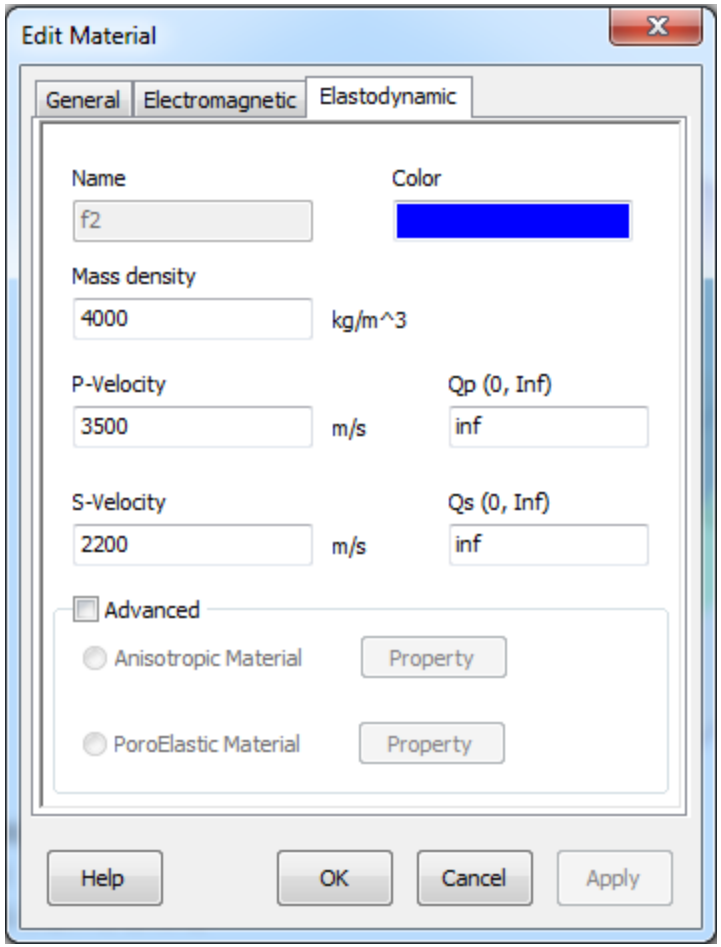


for bottom layer

middle

f2



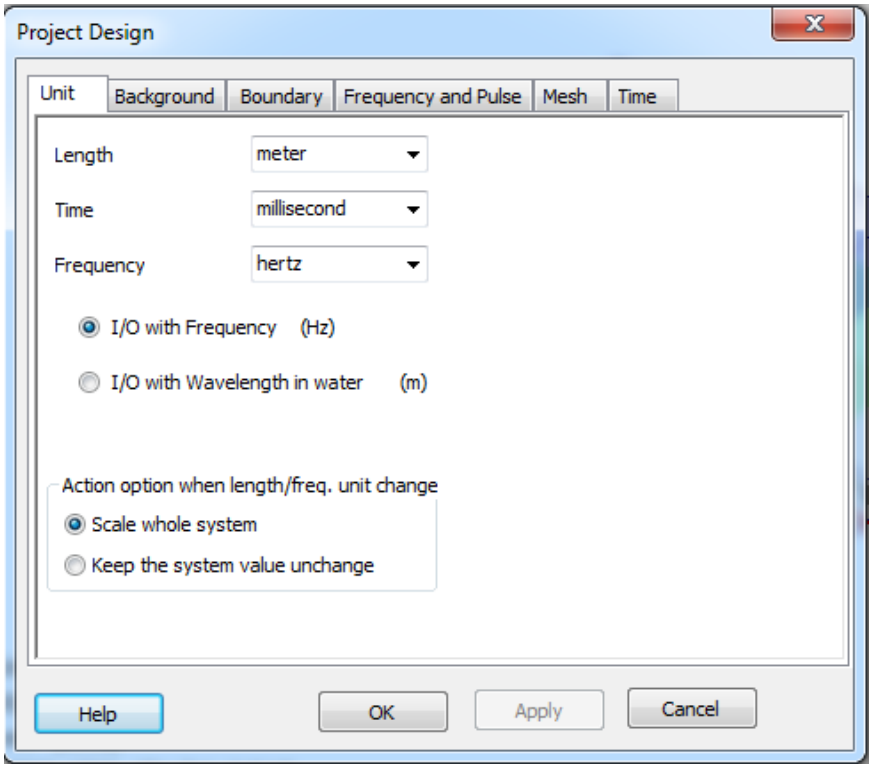


for middle layer

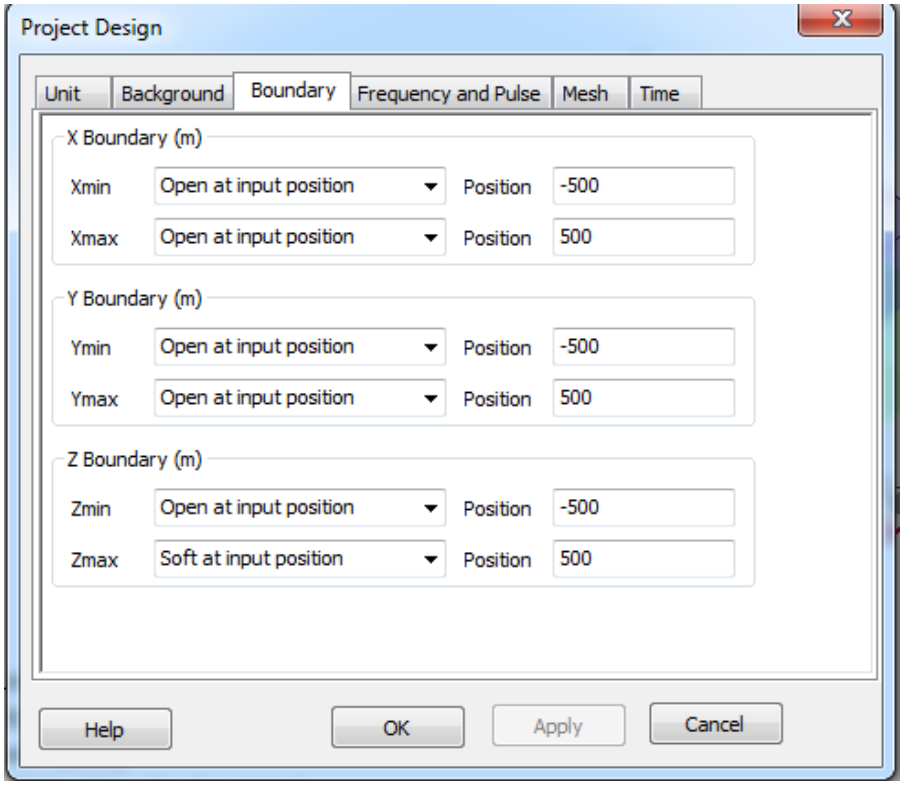
for box

Case setup

Project setting: unit



Project size & B.C.



Project background

Project Design

Unit | Background | Boundary | Frequency and Pulse | Mesh | Time

Homogeneous Background Material: f2

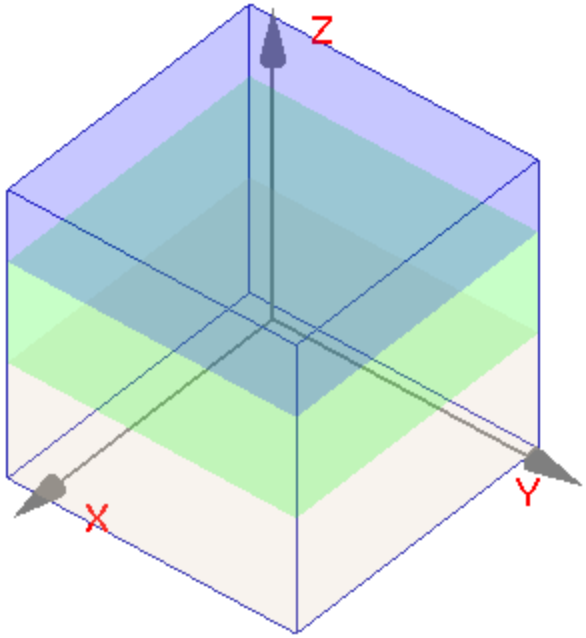
Use Layered Medium

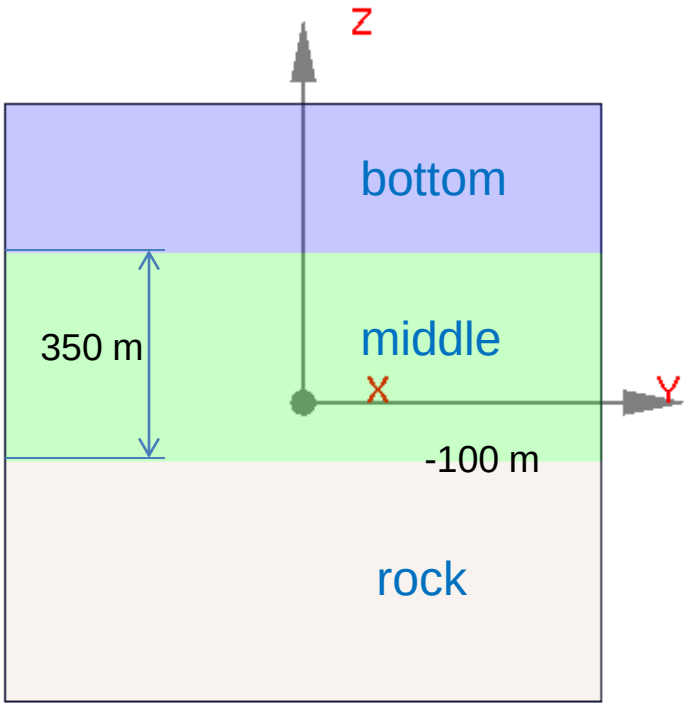
Layer Stack Orientation: Z

(Note: The bottom position and layer thicknesses are along the stack orientation. Double click to begin each cell edit.)

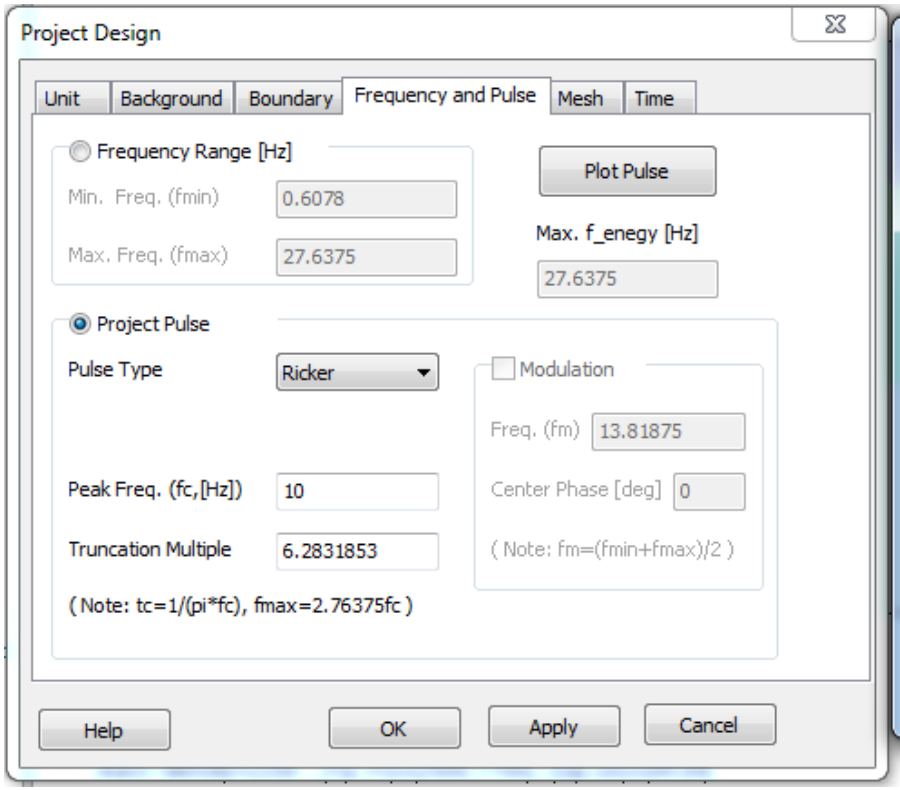
	Bottom Position or Layer Thickness	Material	Action
Top		bottom	
			Add
1	350	middle	Delete
Bottom	-100	rock	

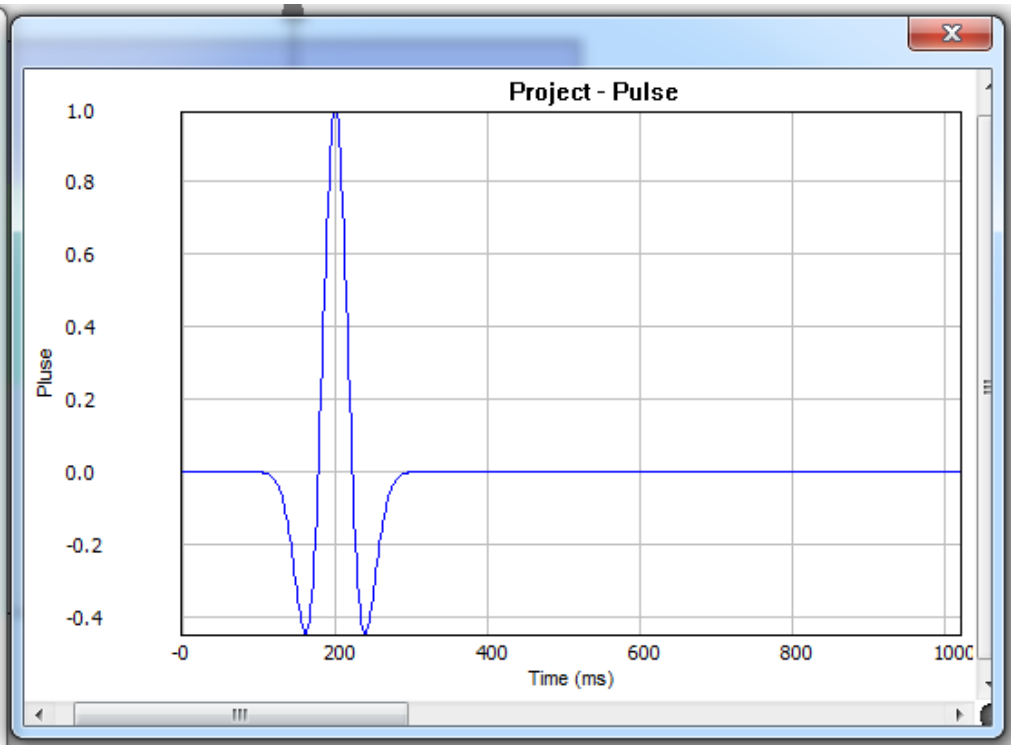
Help | OK | Apply | Cancel



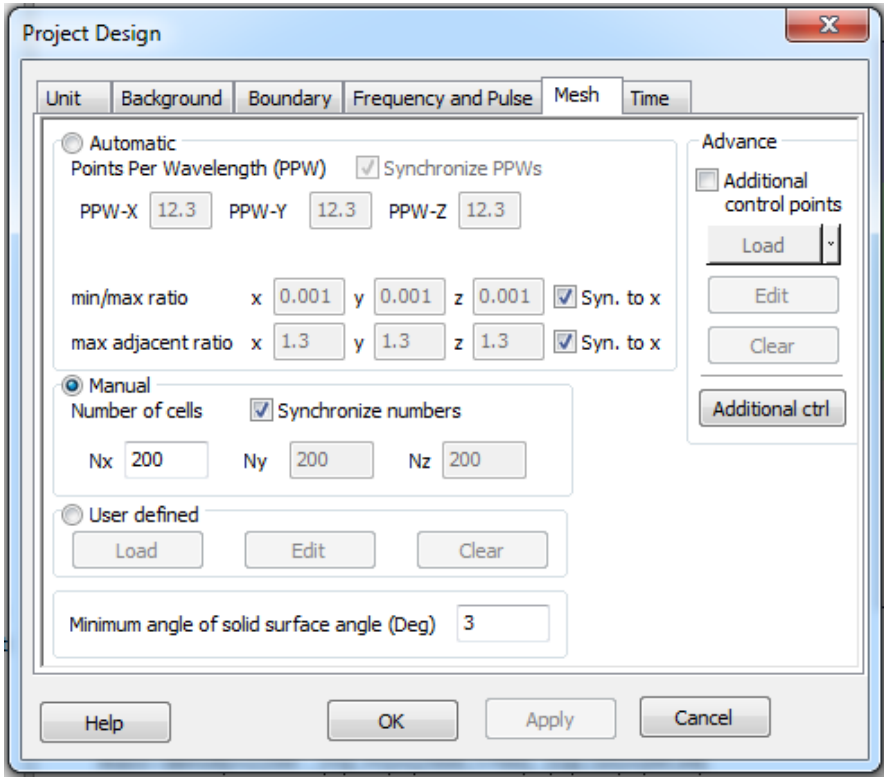


Project pulse: f_c=10 Hz Ricker wave

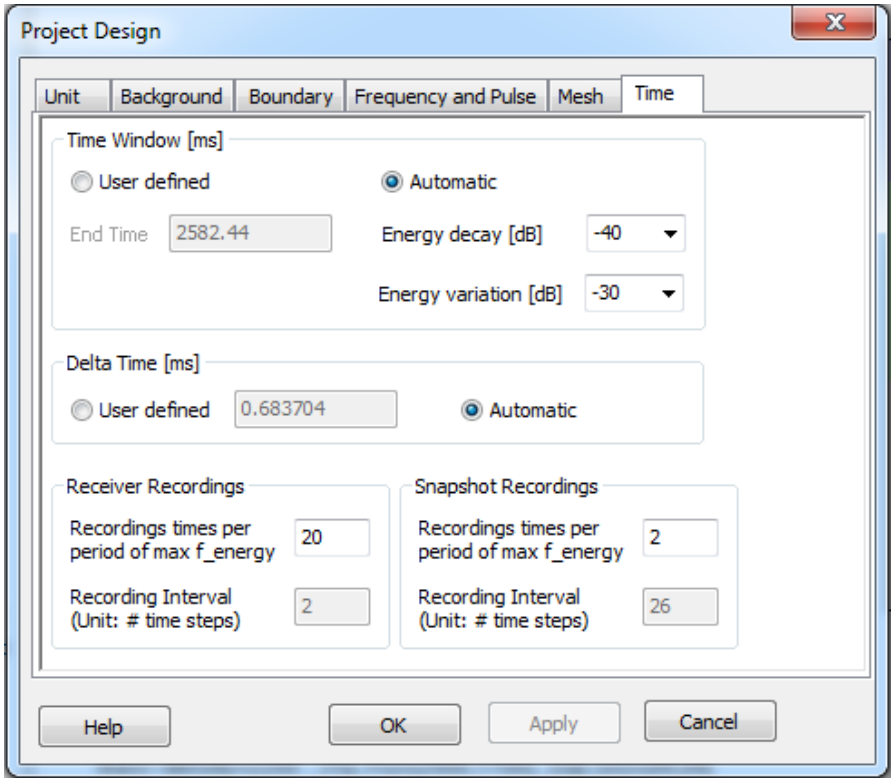




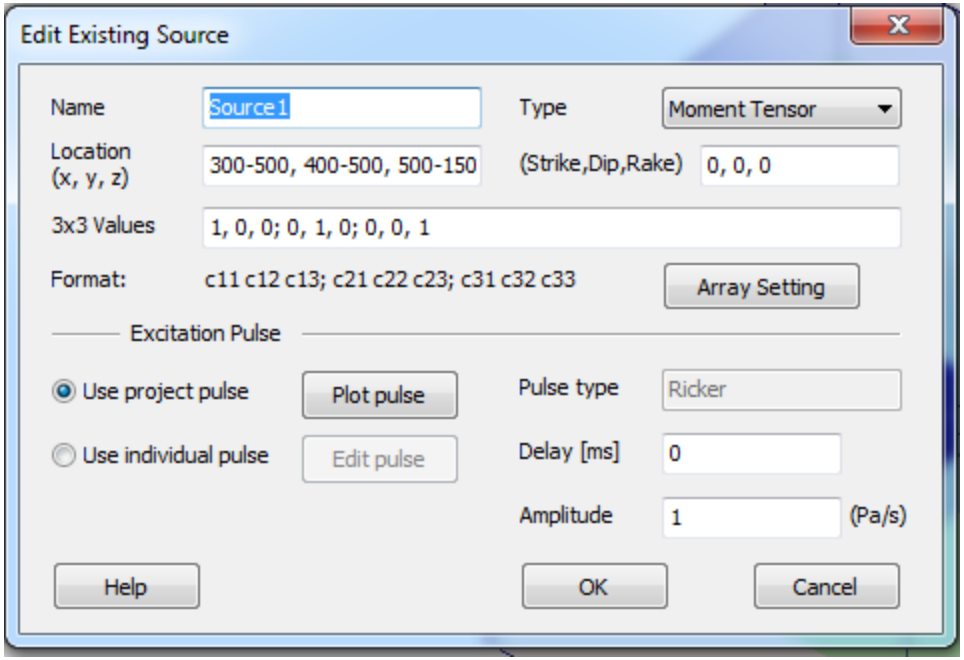
Project mesh: 200 cell in x, y & z

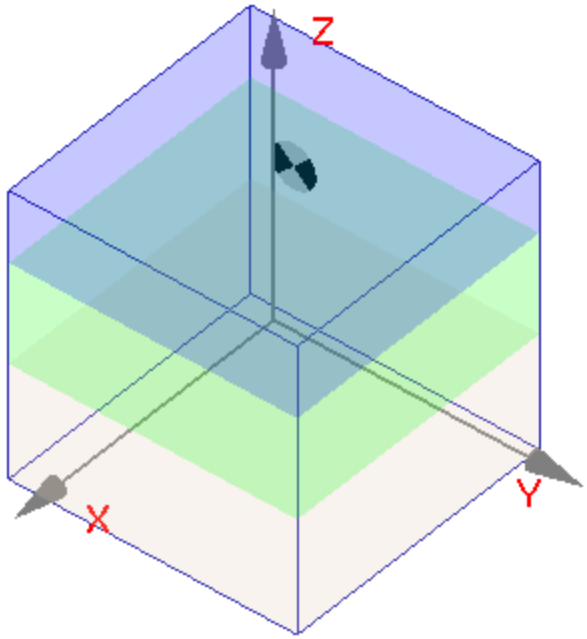


Project time setting: default time window & automatic Δt

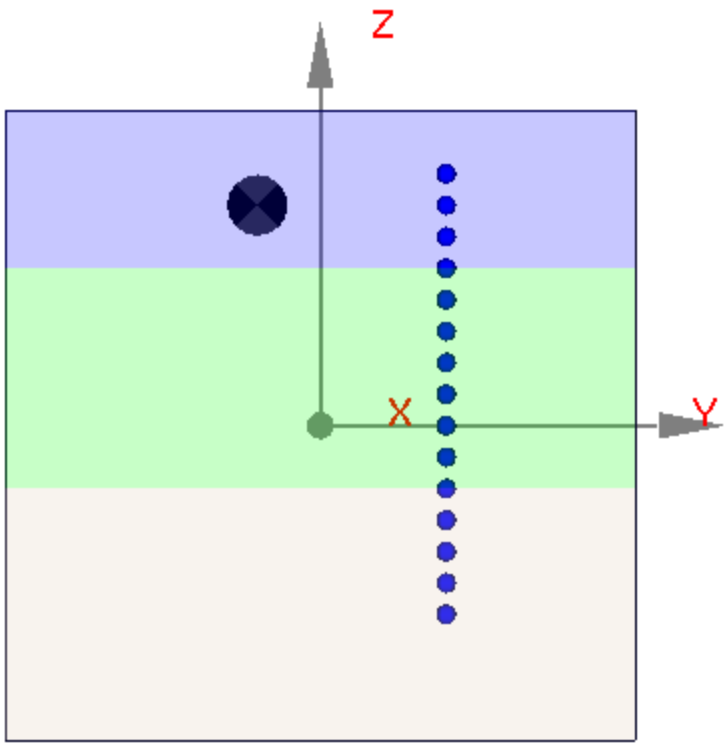


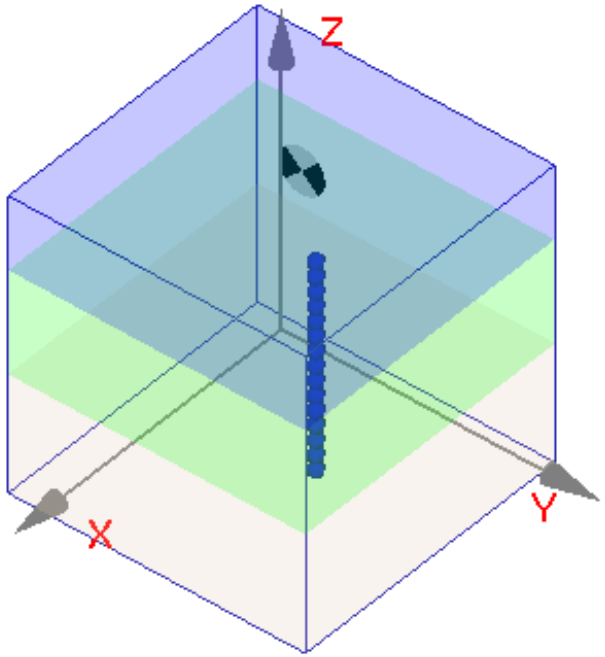
Source: moment tensor at (-200, -100, -350)



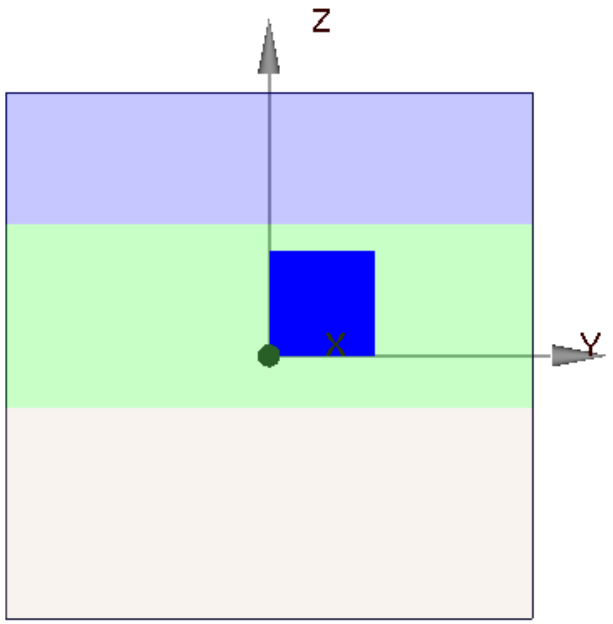


15 observers along z: x=100, y=200; z positions: [400:50:-350]



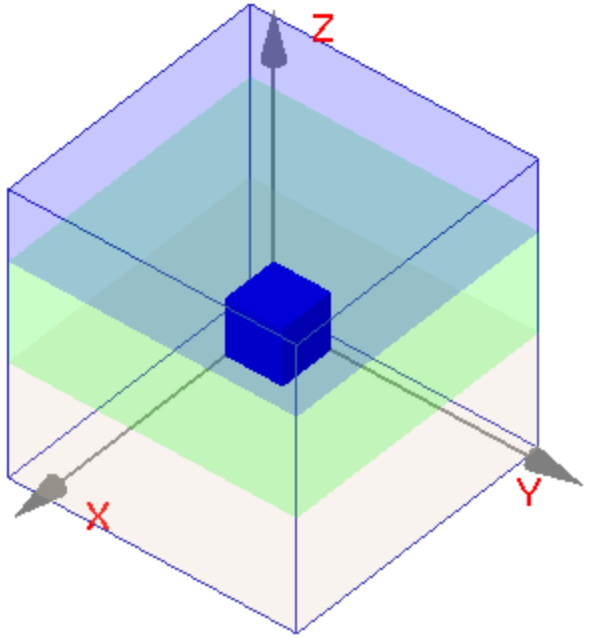


Box region



As right figure.

Size: (0,0,0)-(200,200,200)
Material: f2
mass: 4000
vp: 3500
vs: 2200



But in this case, we will use a voxel to represent this: (0,0,0)-(200,200,200) rectangular region instead of a regular box

Prepare voxel data files

This is a rectangular region with regular isotropic EL material, so, we need only 3 inputs: mass, vp, vs.

Assuming this voxel is composed by: 2x2x2=8 uniform cells (cell size is 100x100x100 m^3), each cell's material is defined by file (ASCII format), we can define 3 files for each input, as following,

Mass.txt

```
2
2
2

4000
4000

4000
4000

4000
4000

4000
4000
```

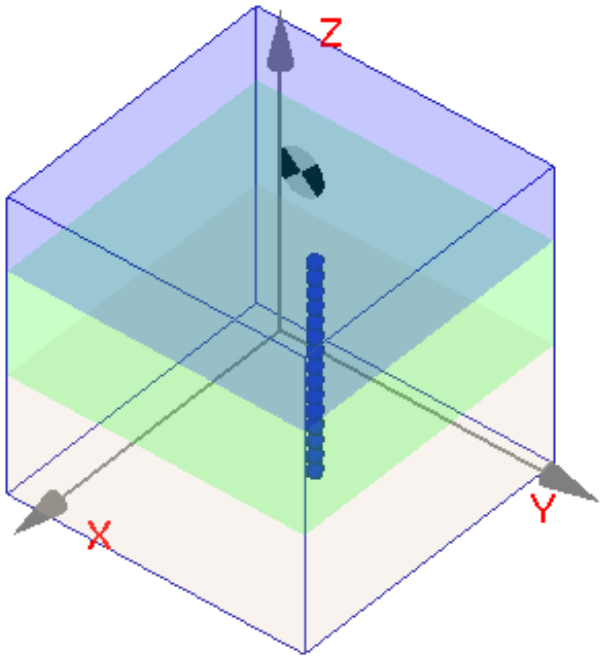
Vp.txt

```
2
2
2

3500
3500

3500
3500

3500
3500

3500
3500
```

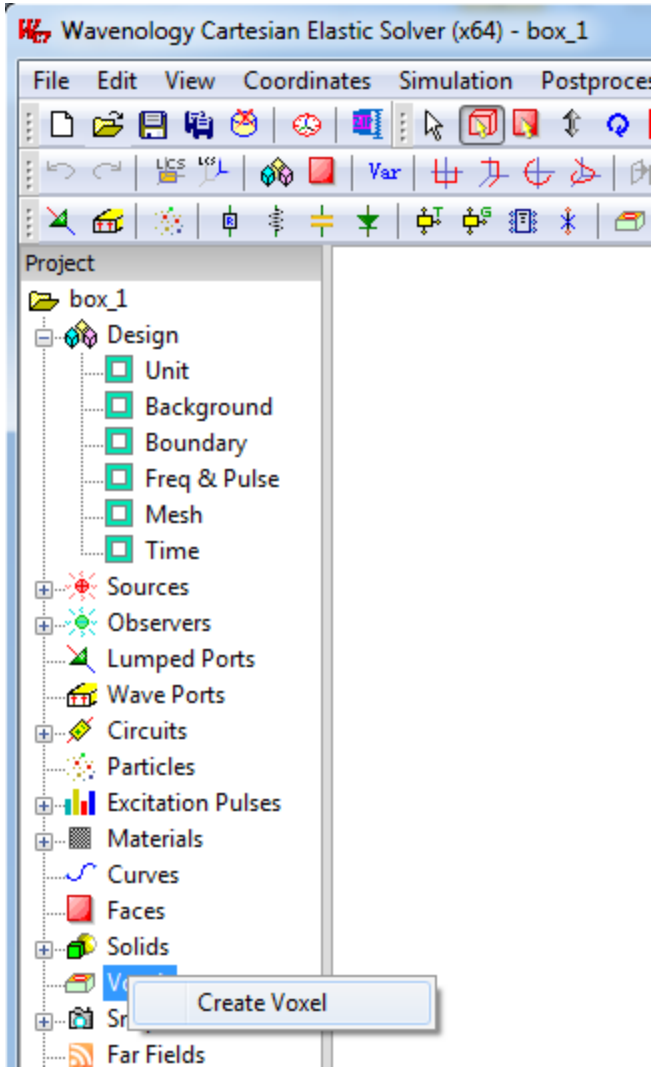
Vs.txt

```
2
2
2

2200
2200

2200
2200

2200
2200

2200
2200
```

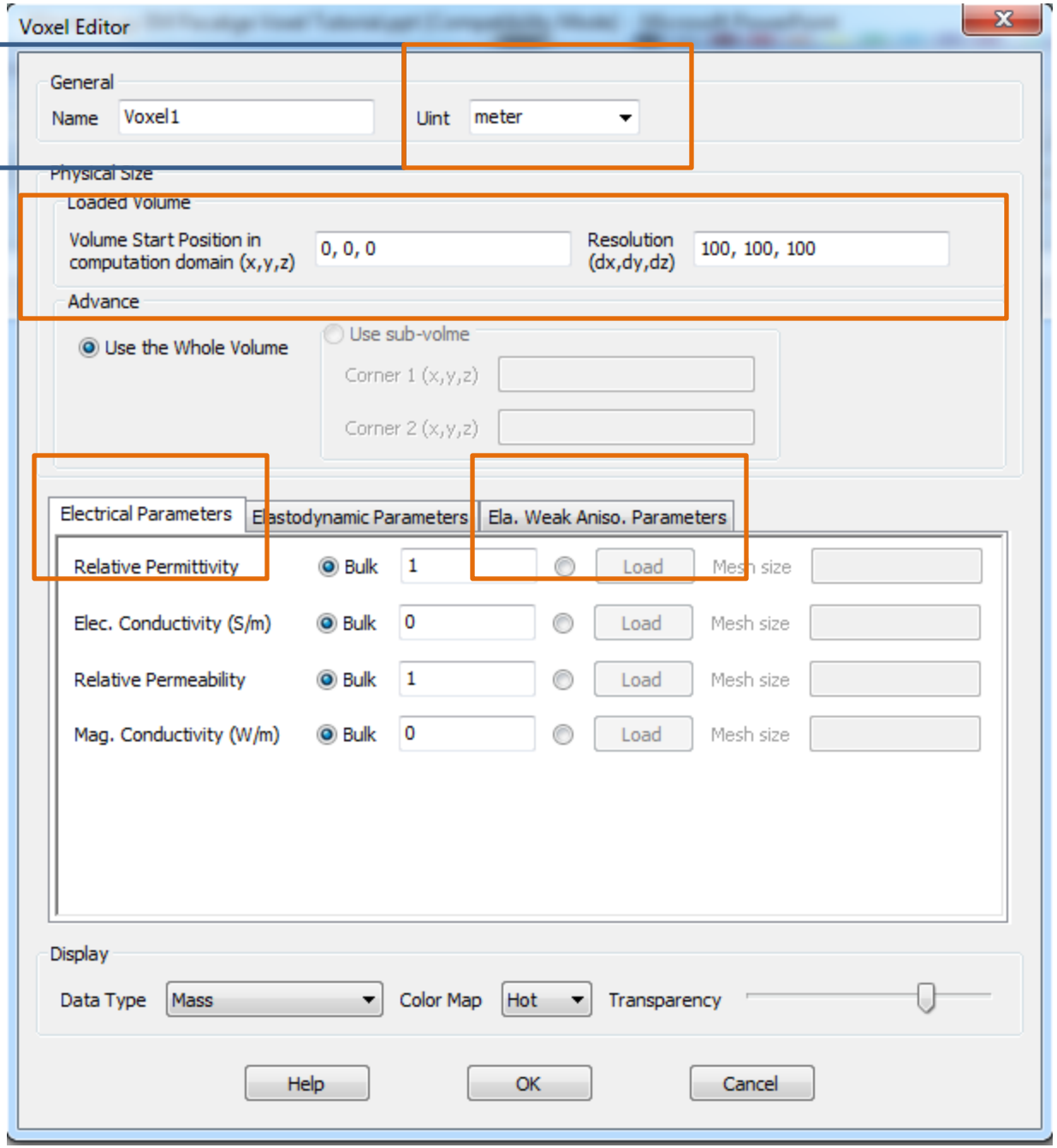
After project setup, source and receiver, voxel data files are ready, we can see the project as following



Then, create voxel



Voxel name

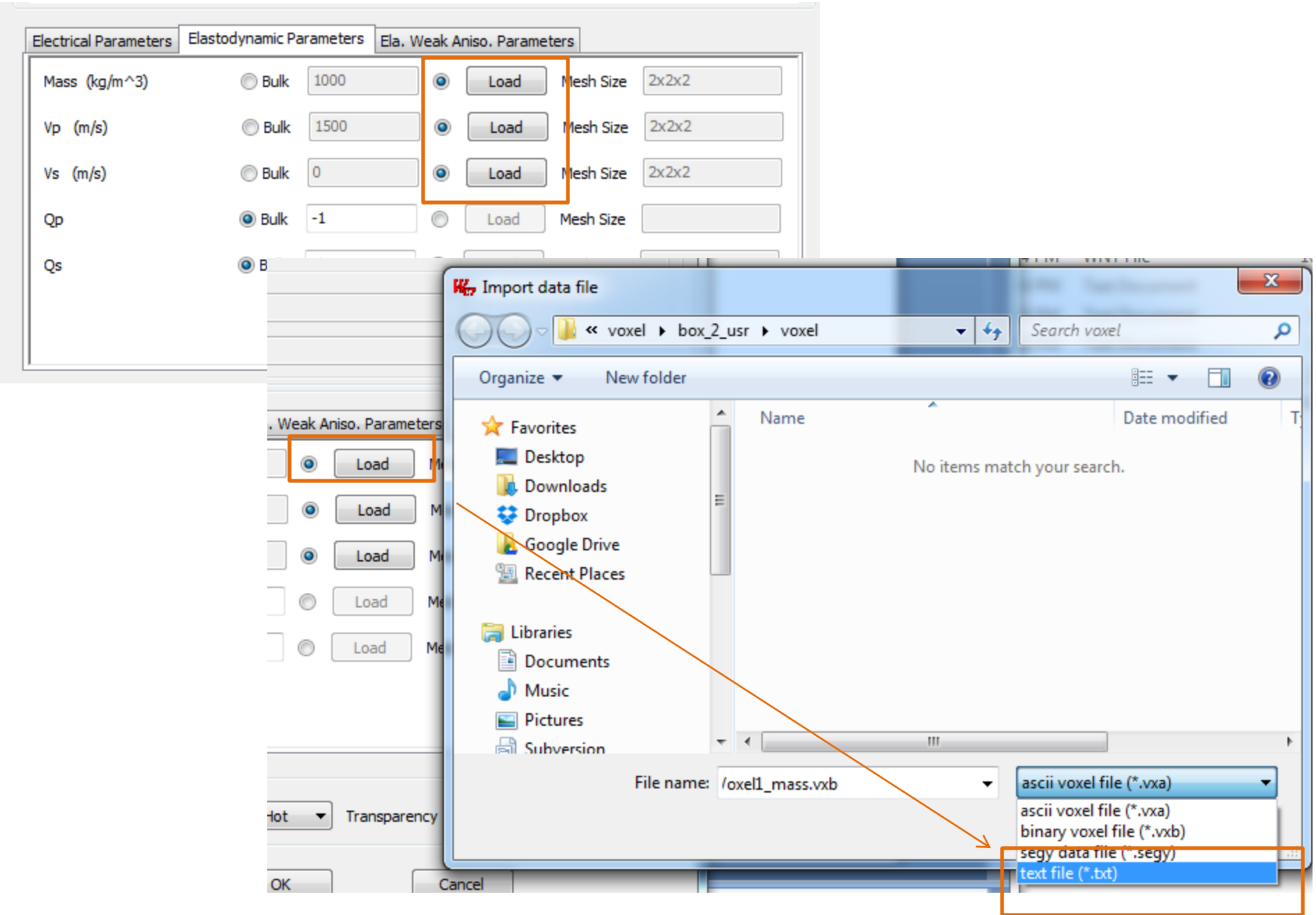


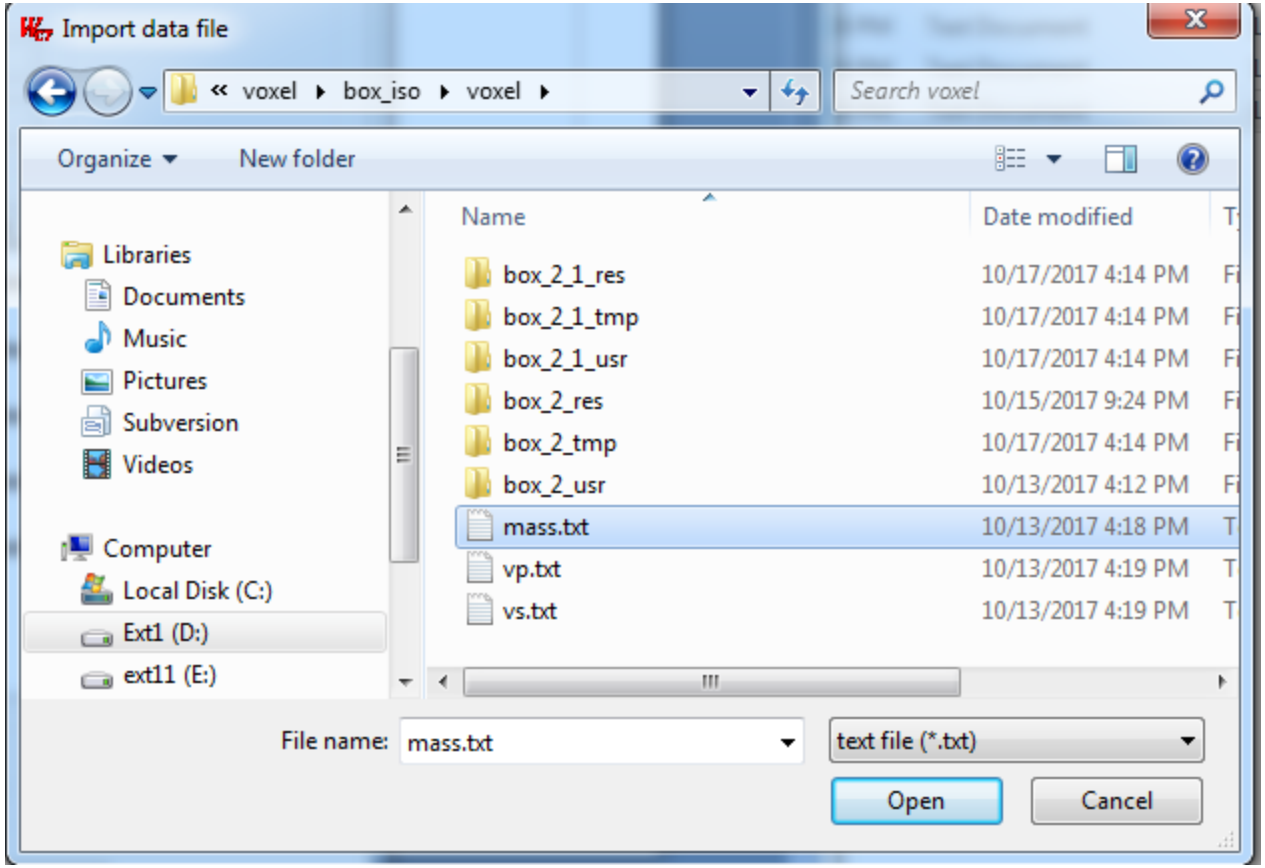
Voxel unit

Voxel start position & resolution

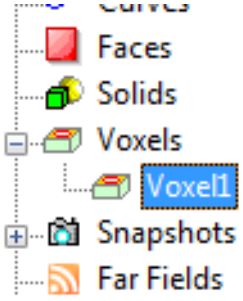
Skip pages: Electrical parameters & Ela. Weak Aniso. Parameters

In the Elastodynamic Parameters page, load mass, vp, vs from TXT data files, respectively.

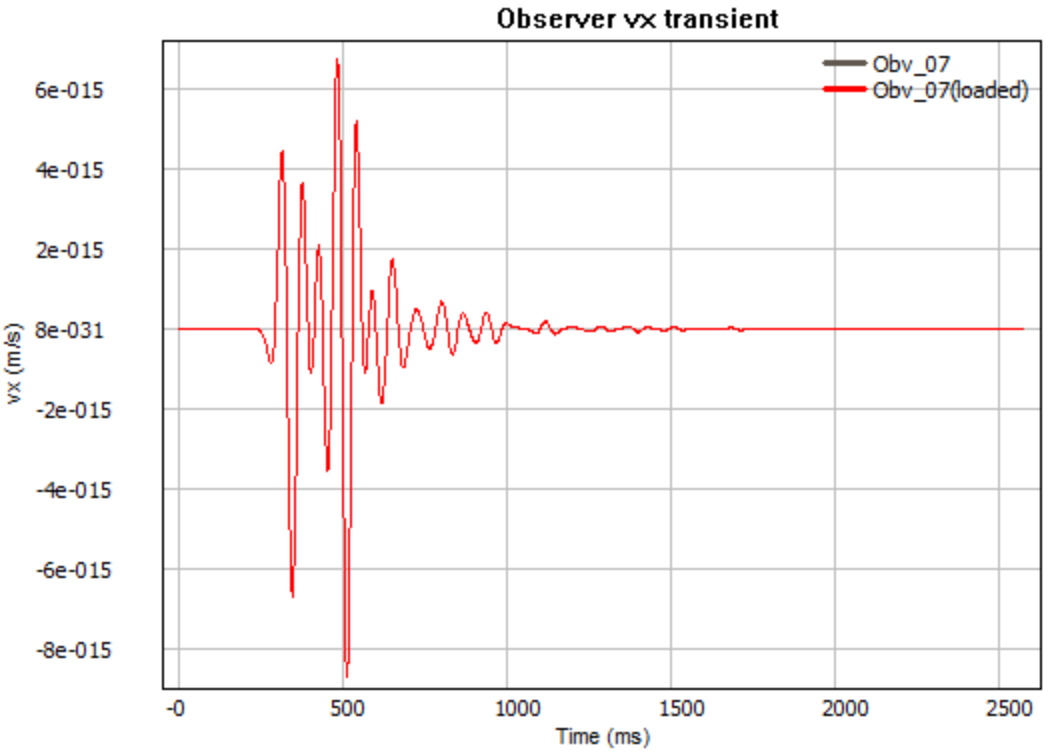




After all voxel parameters are set correctly, then “OK” to add this voxel in the project, as right figure



Then we can simulate this project, and compare the simulation result with a regular box setting. We can see two sets of data overlap.



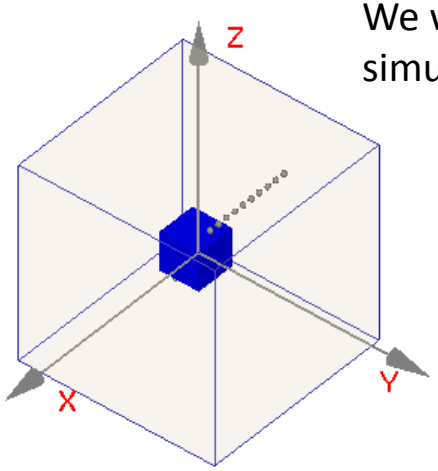
Voxel

Regular box

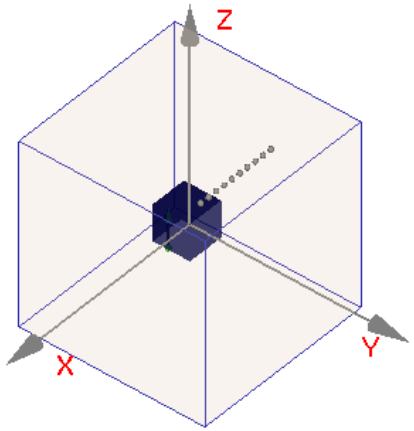
Case (2) a Box in Homogenous Background

weak anisotropic material

This case simulates a box with anisotropic material in a homogenous background. We will show how to define this box by the voxel way and compare the simulation result with the result by defining a box by a normal way.



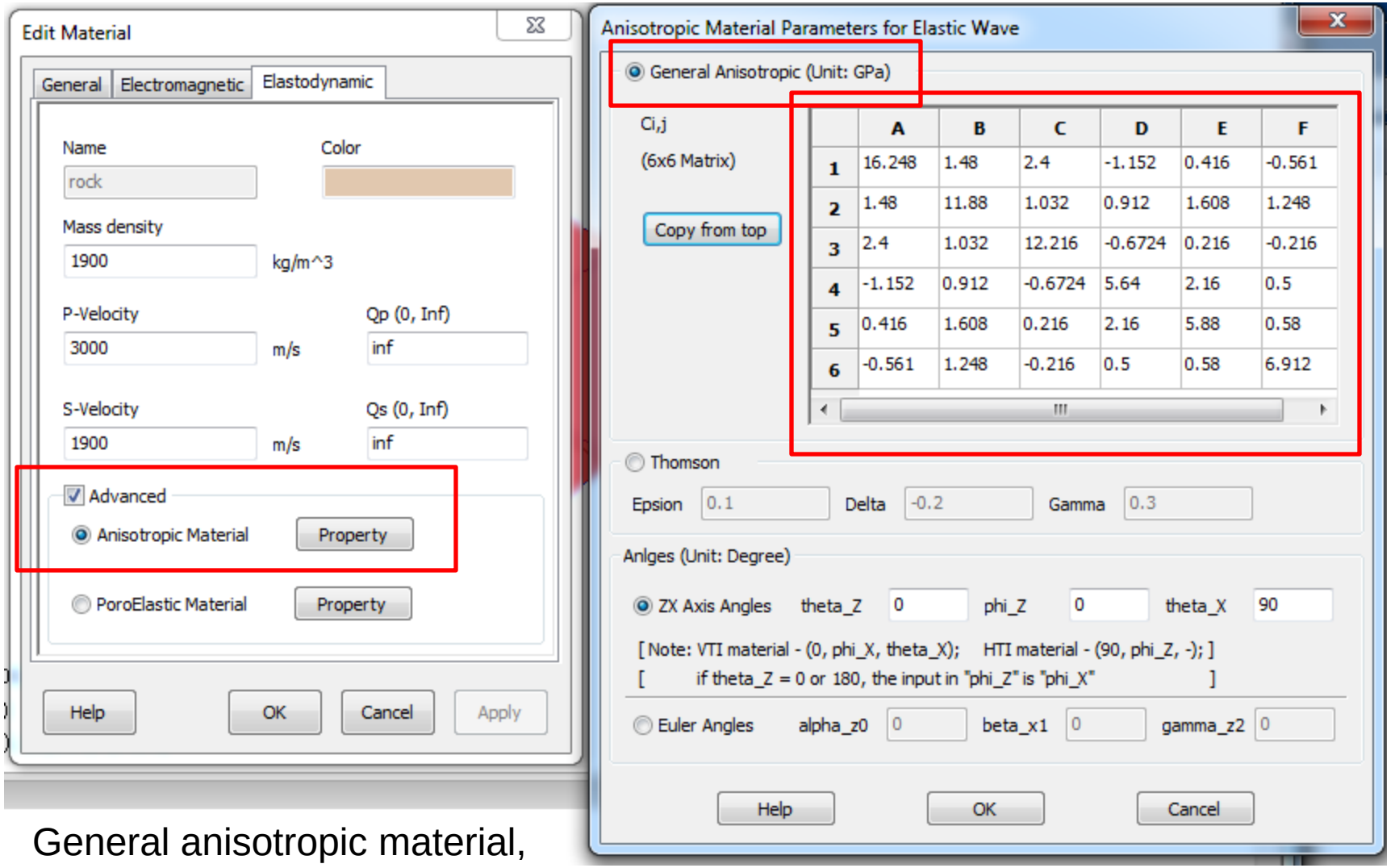
The left Fig. is the reference case, a regular box in a homogenous background.



In the voxel case, we will replace the box region by a voxel with 2x2x2 cells, and then compare the transient response on receiver in two cases.

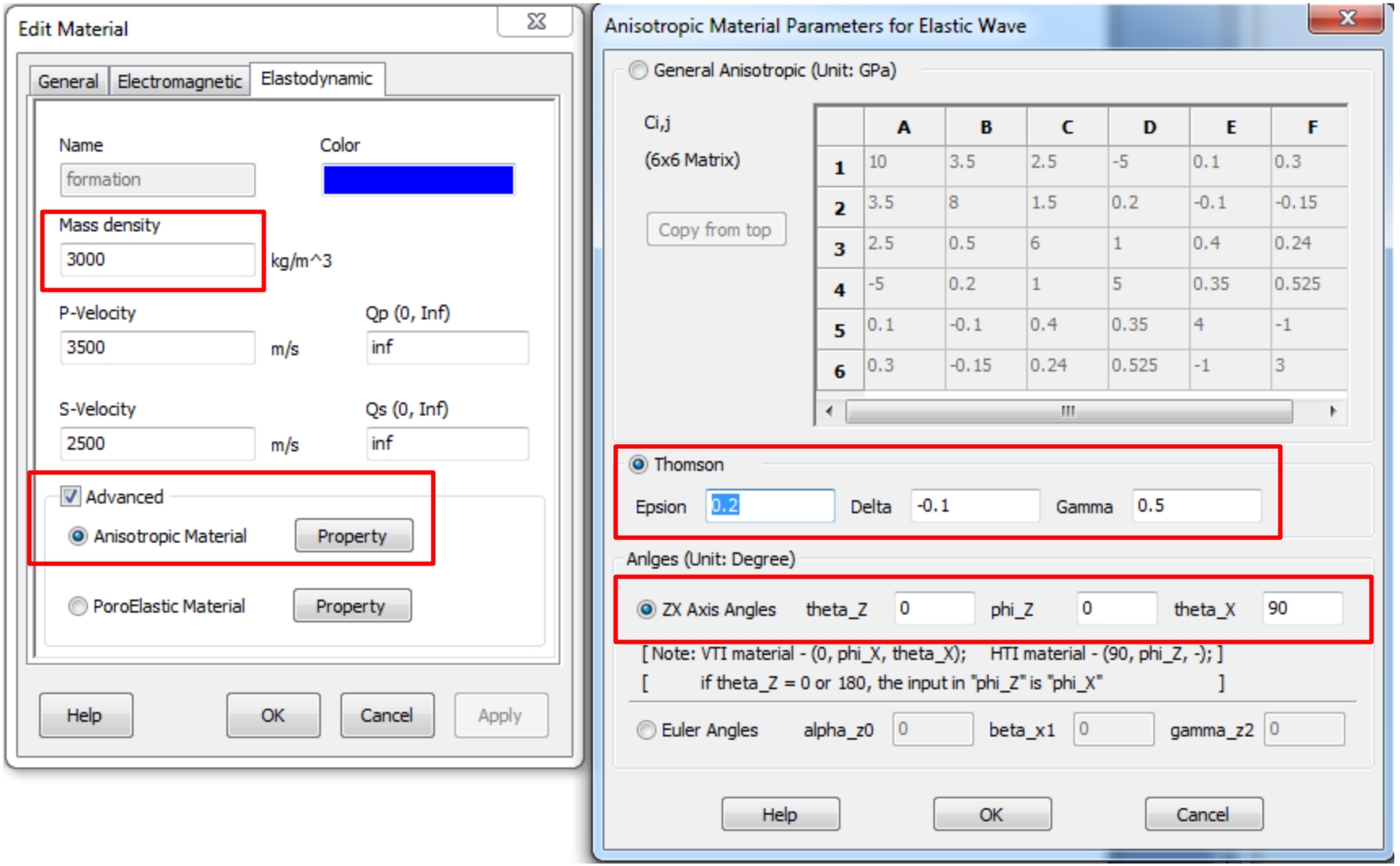
Case setup: Materials

Rock



General anisotropic material, for background

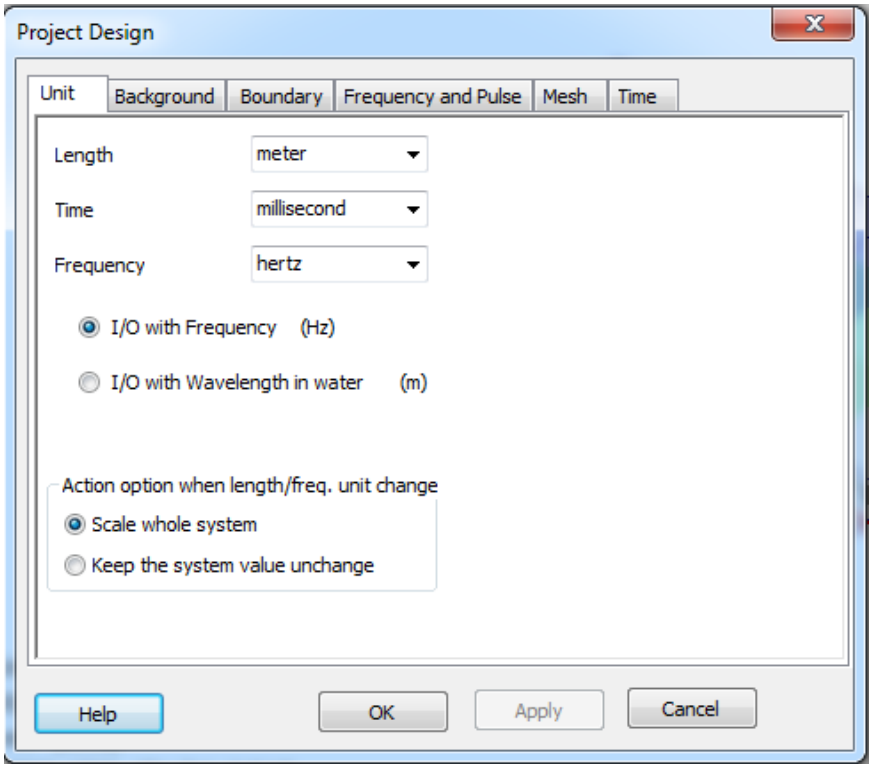
The VTI anisotropic material for the voxel has following properties



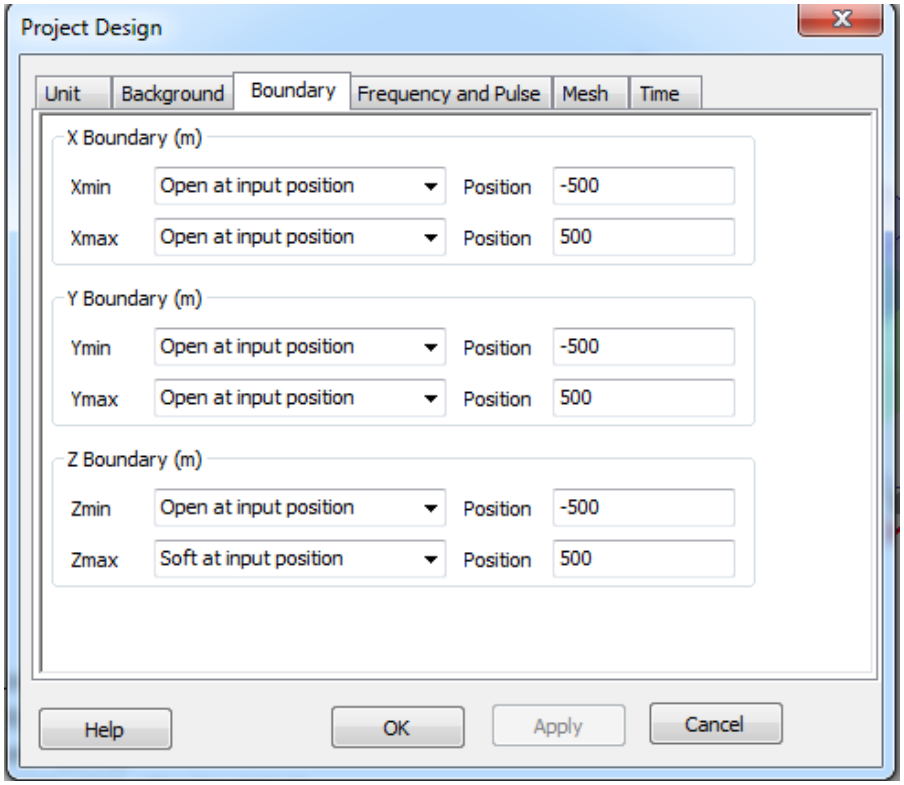
This property is for information purpose only , user can skip the definition of this material in the project setup

Case setup

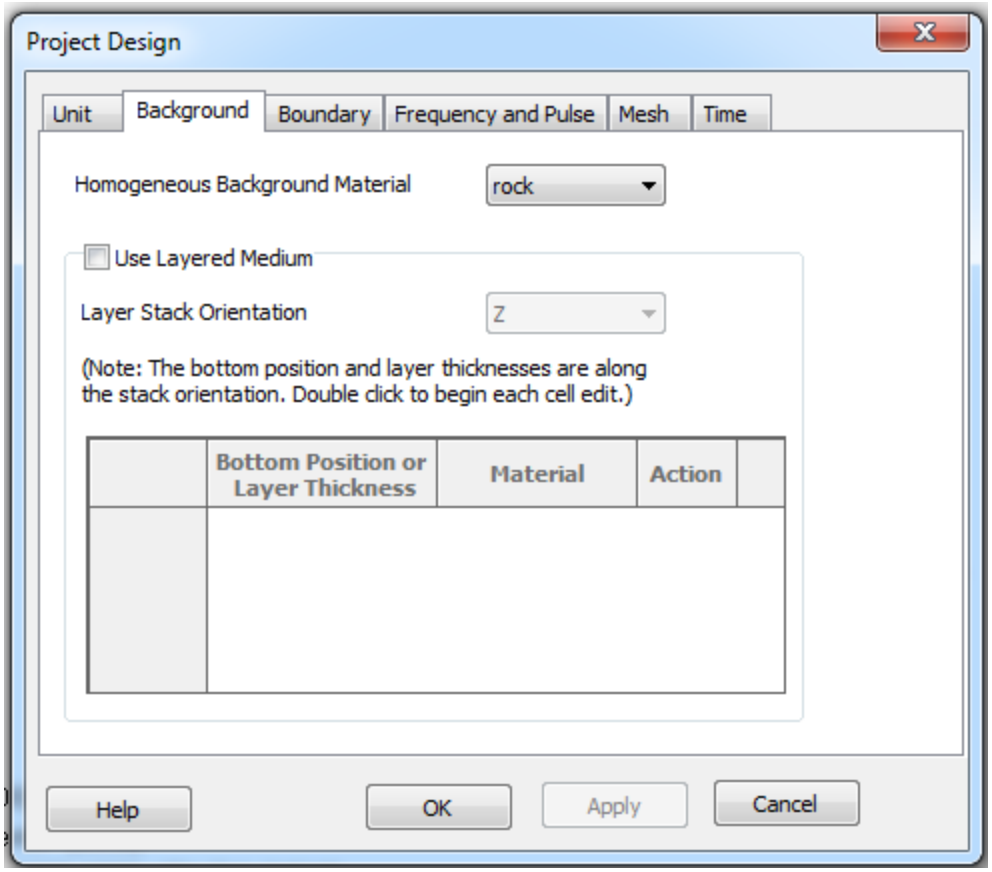
Project setting: unit



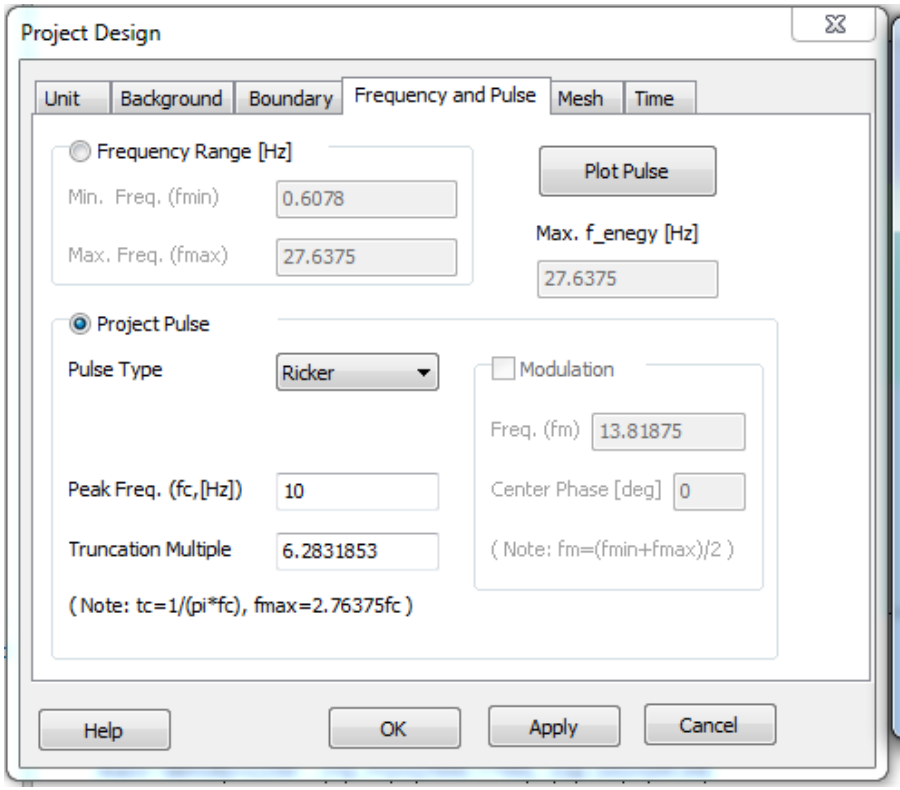
Project size & B.C.

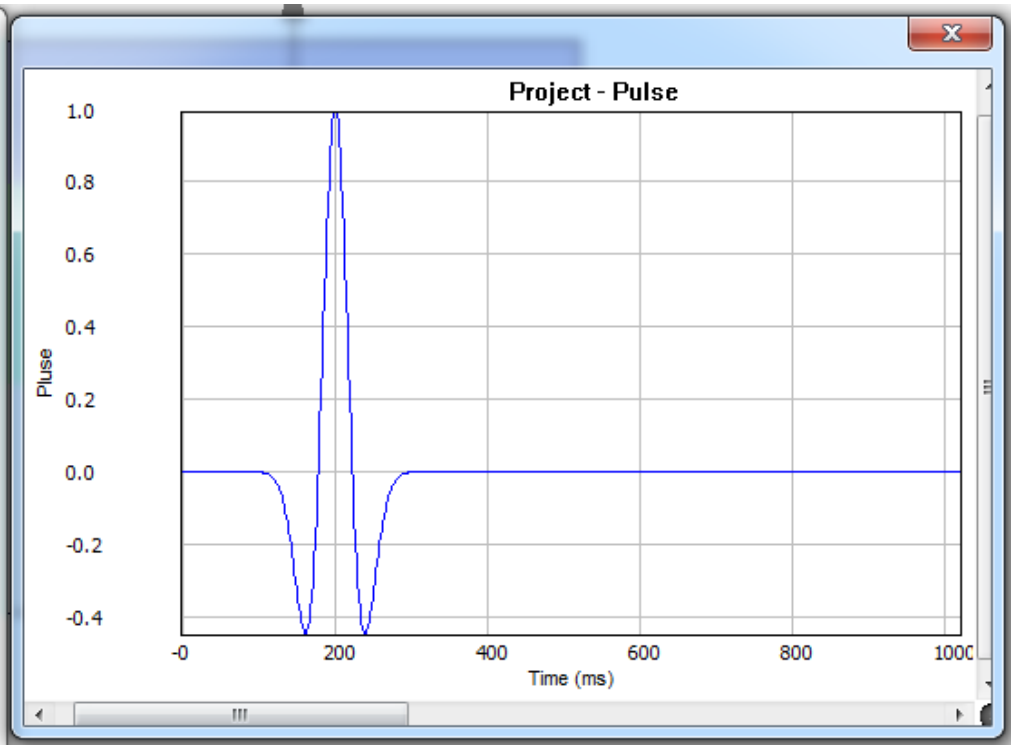


Project background



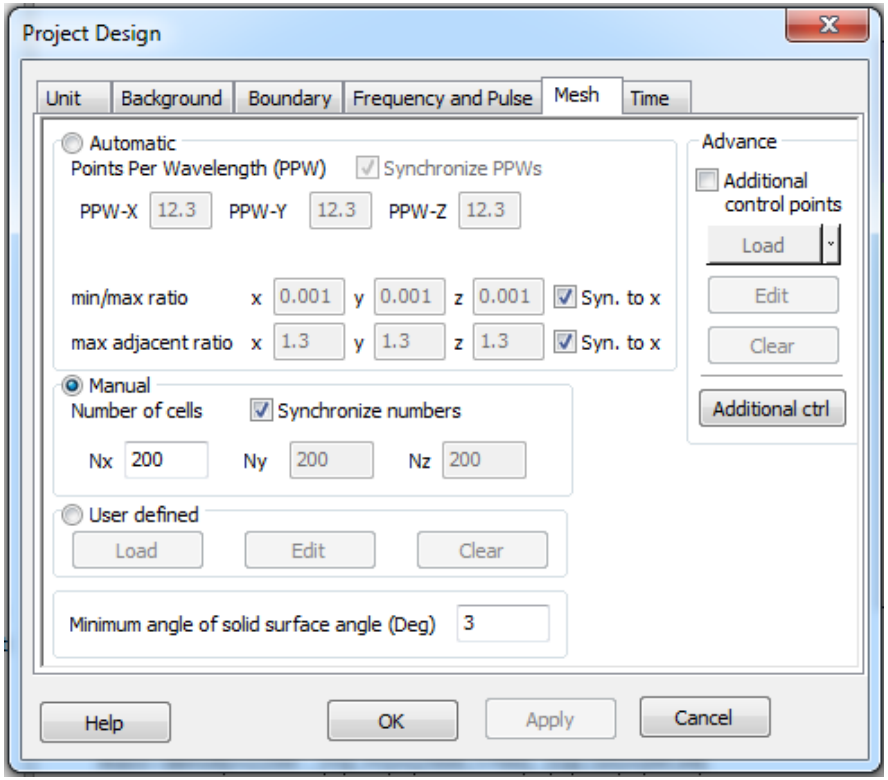
Project pulse: f_c=10 Hz Ricker wave

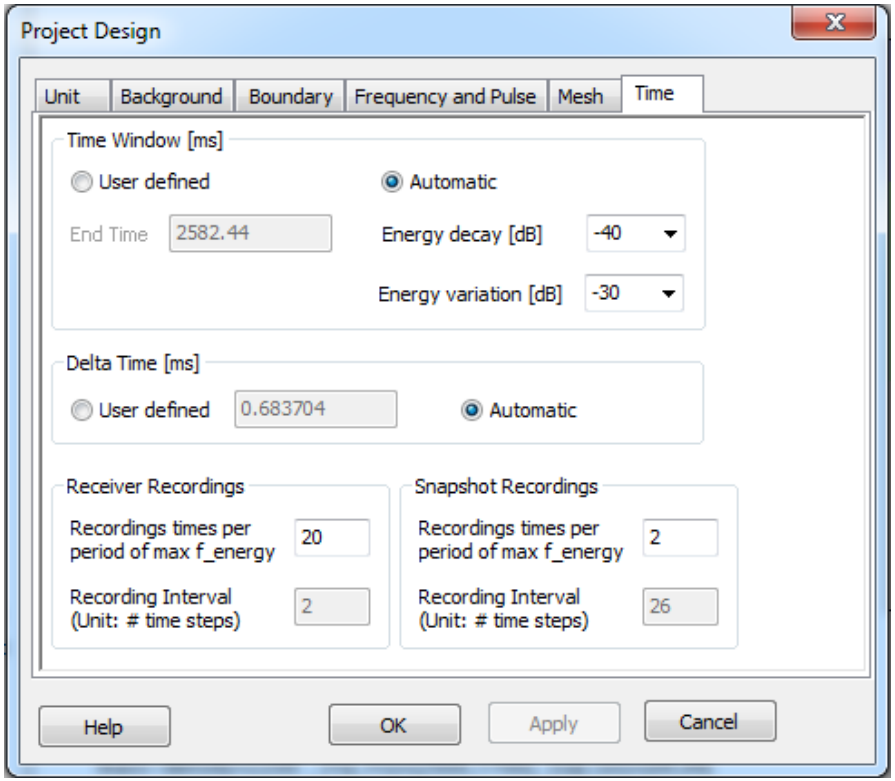




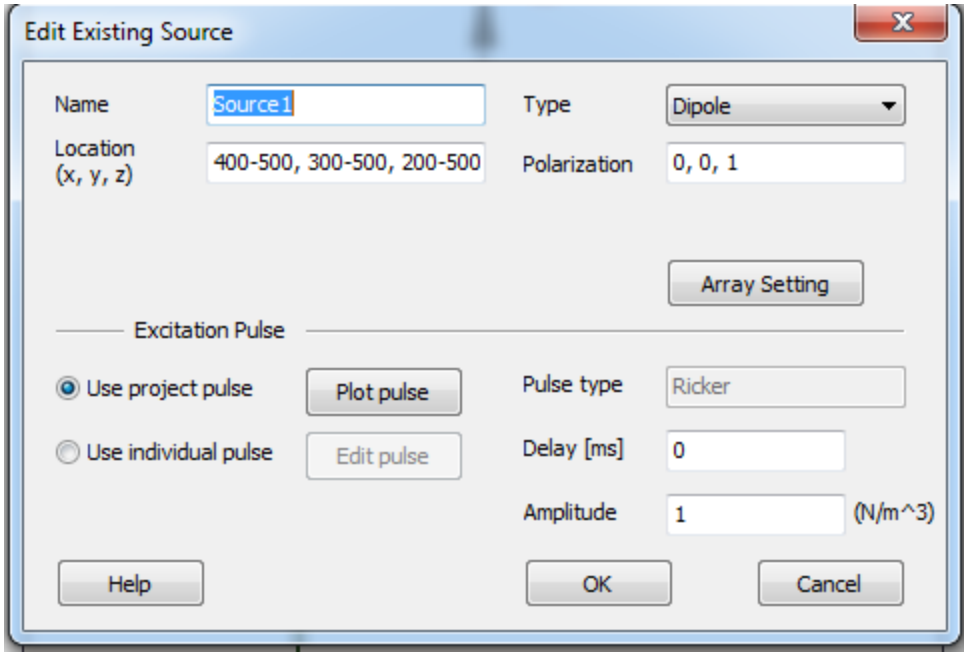
Project mesh: 200 cell in x, y & z

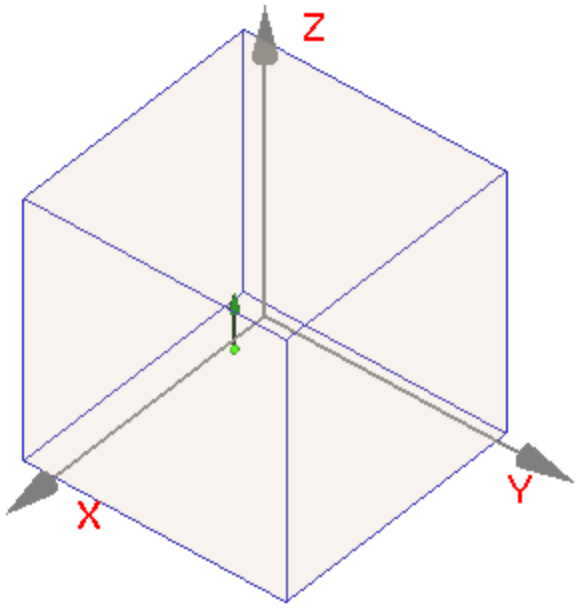
Project time setting: default time window & automatic Δt



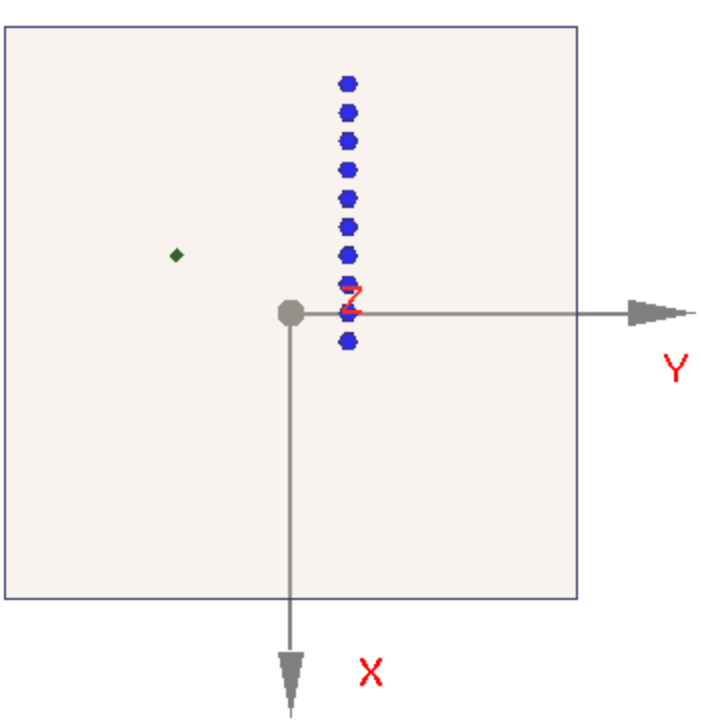


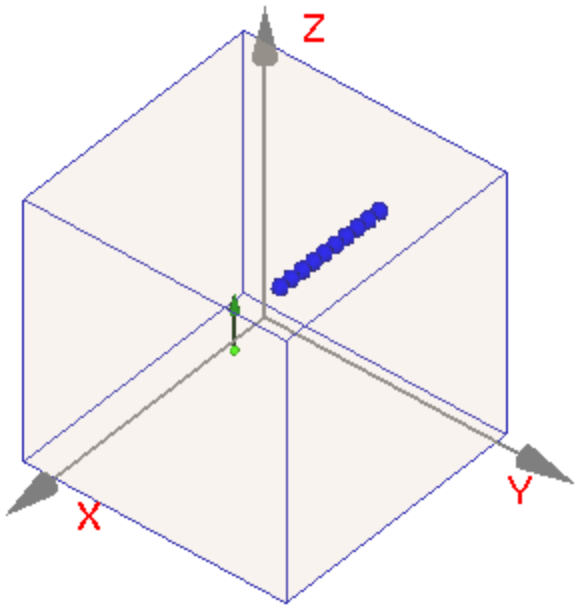
Source: Z polarization point dipole source at (-100, -200, -300)





10 observers along x: y=100, z=200; x positions: [-400:50:50]

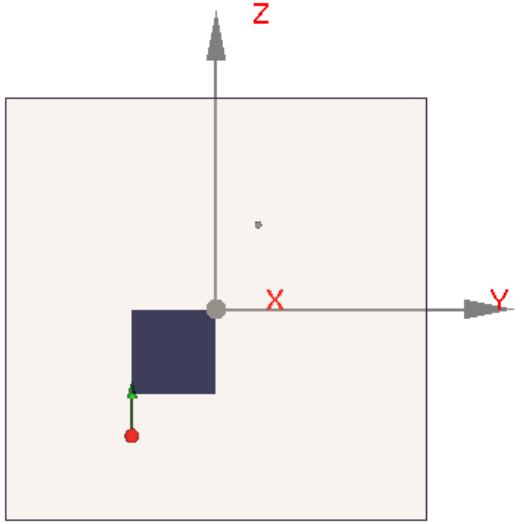


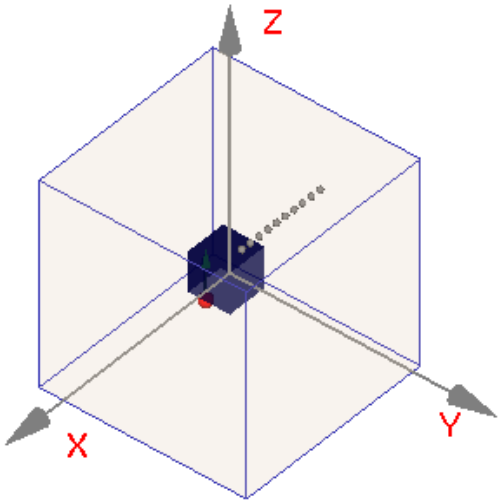


Box region

As right figure.

Size: (200,-200,-200)- (0,0,0)
Material is the one we shown in the project material page





Prepare voxel data files

This is a rectangular region with weak anisotropic EL material (VTI material, Thomson type). Here, we need only 3 inputs: epsilon, delta, gamma. The material rotation angle for each cell is bulk value.

Assuming this voxel is composed by: 2x2x2=8 uniform cells (cell size is 100x100x100 m^3), each cell's material is defined by file (ASCII format), we can define 3 files for each input, as following,

epsilon.txt

```
2
2
2

0.2
0.2

0.2
0.2

0.2
0.2

0.2
0.2
```

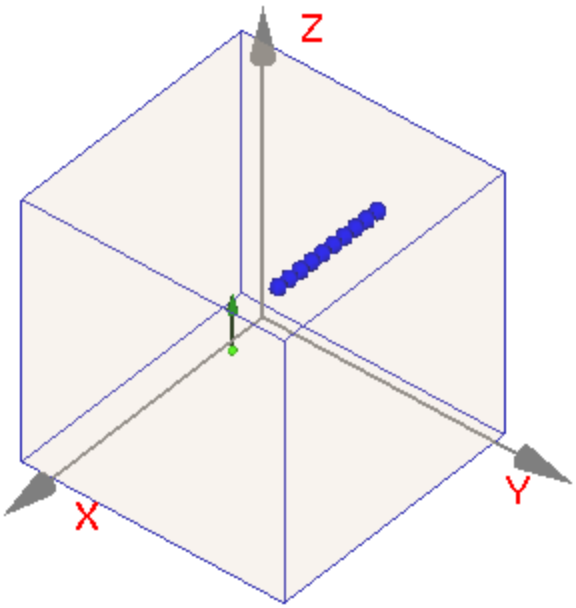
delta.txt

```
2
2
2

-0.1
-0.1

-0.1
-0.1

-0.1
-0.1

-0.1
-0.1
```

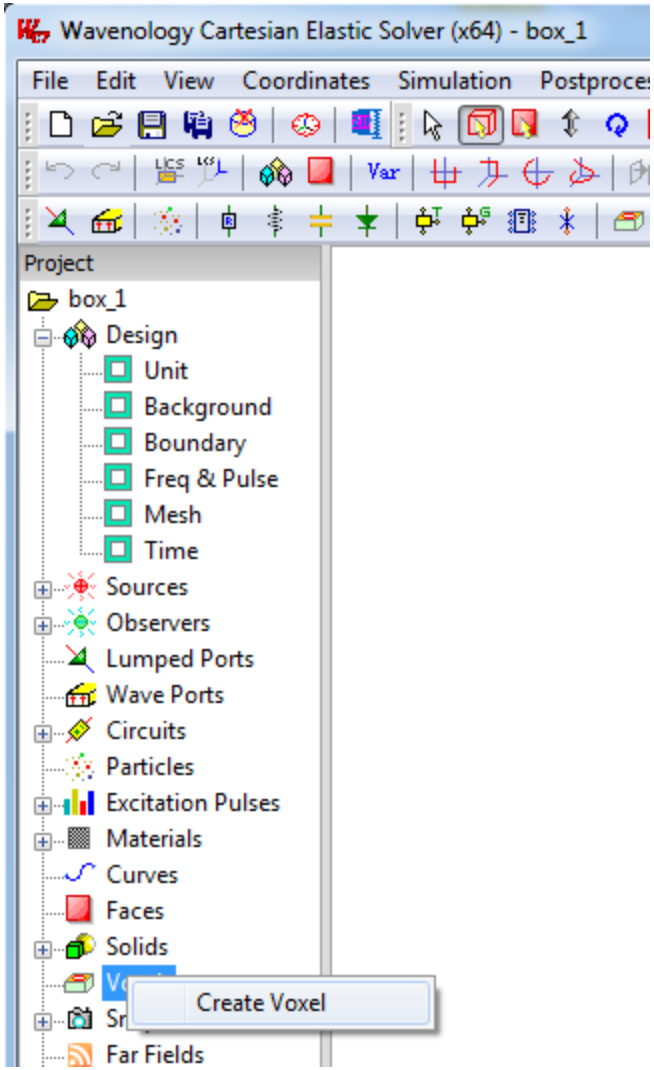
gamma.txt

```
2
2
2

0.5
0.5

0.5
0.5

0.5
0.5

0.5
0.5
```

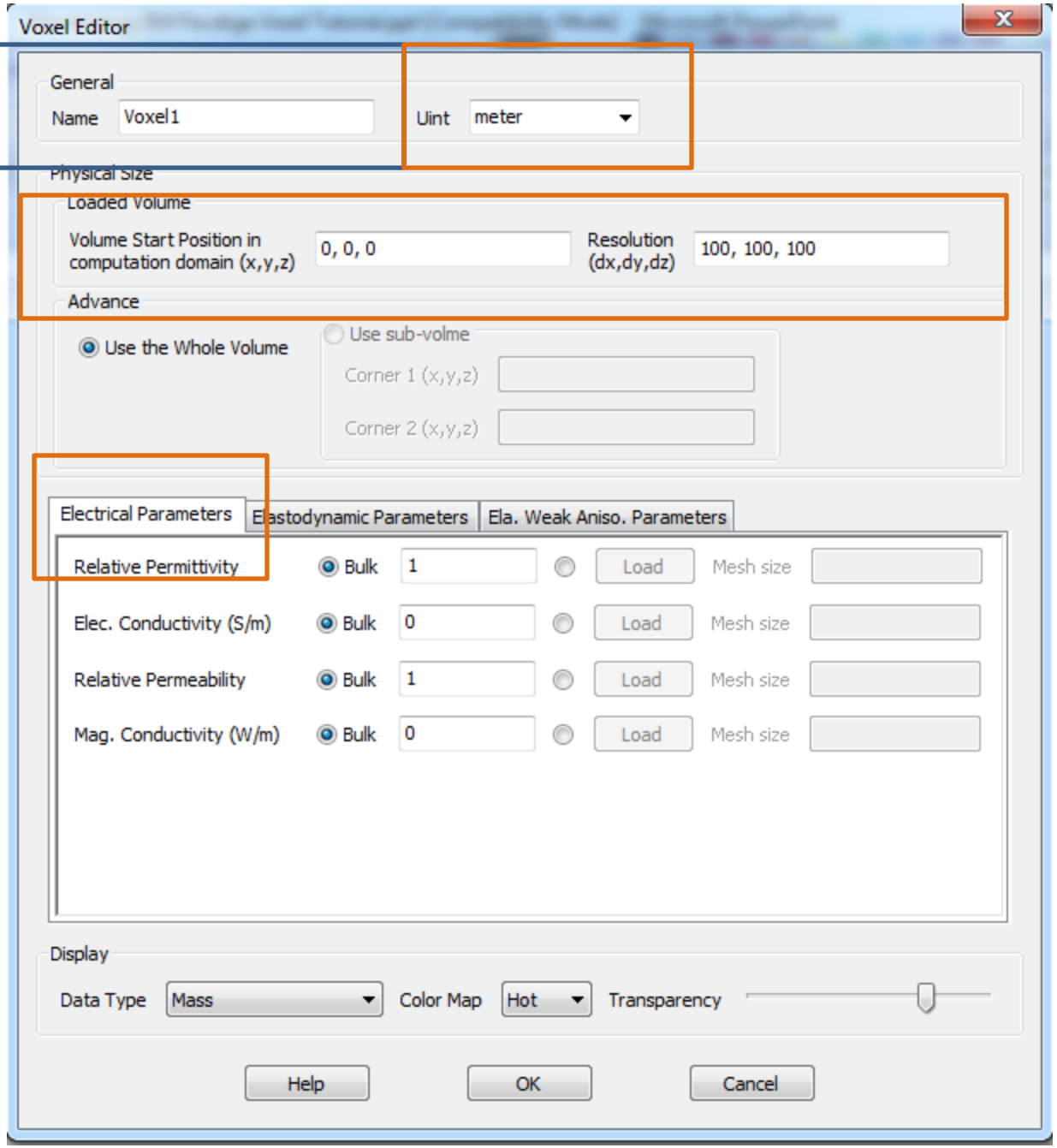
After project setup, source and receiver, voxel data files are ready, we can see the project as following



Then, create voxel



Voxel name



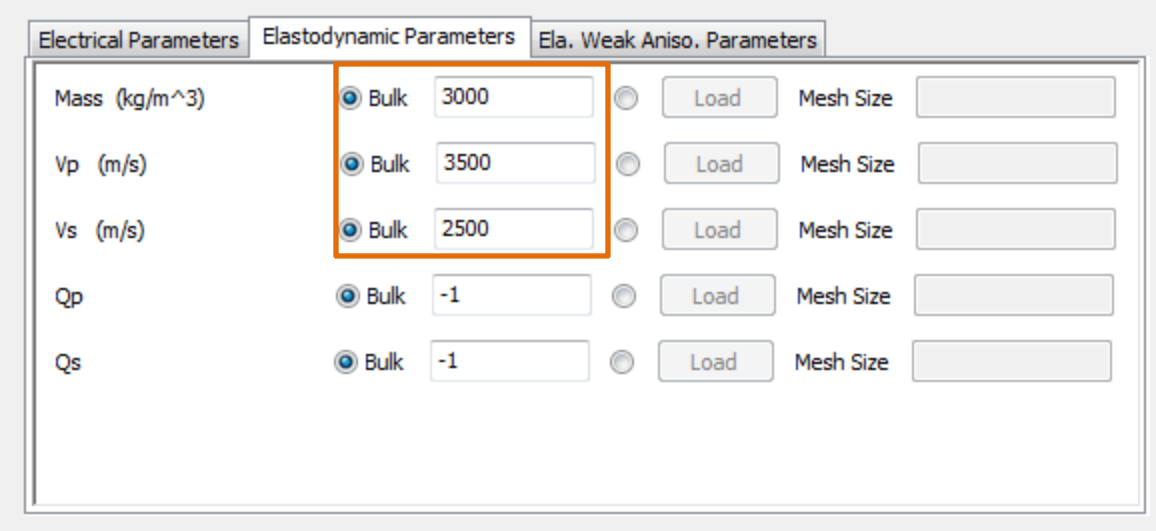
Voxel unit

Voxel start position & resolution

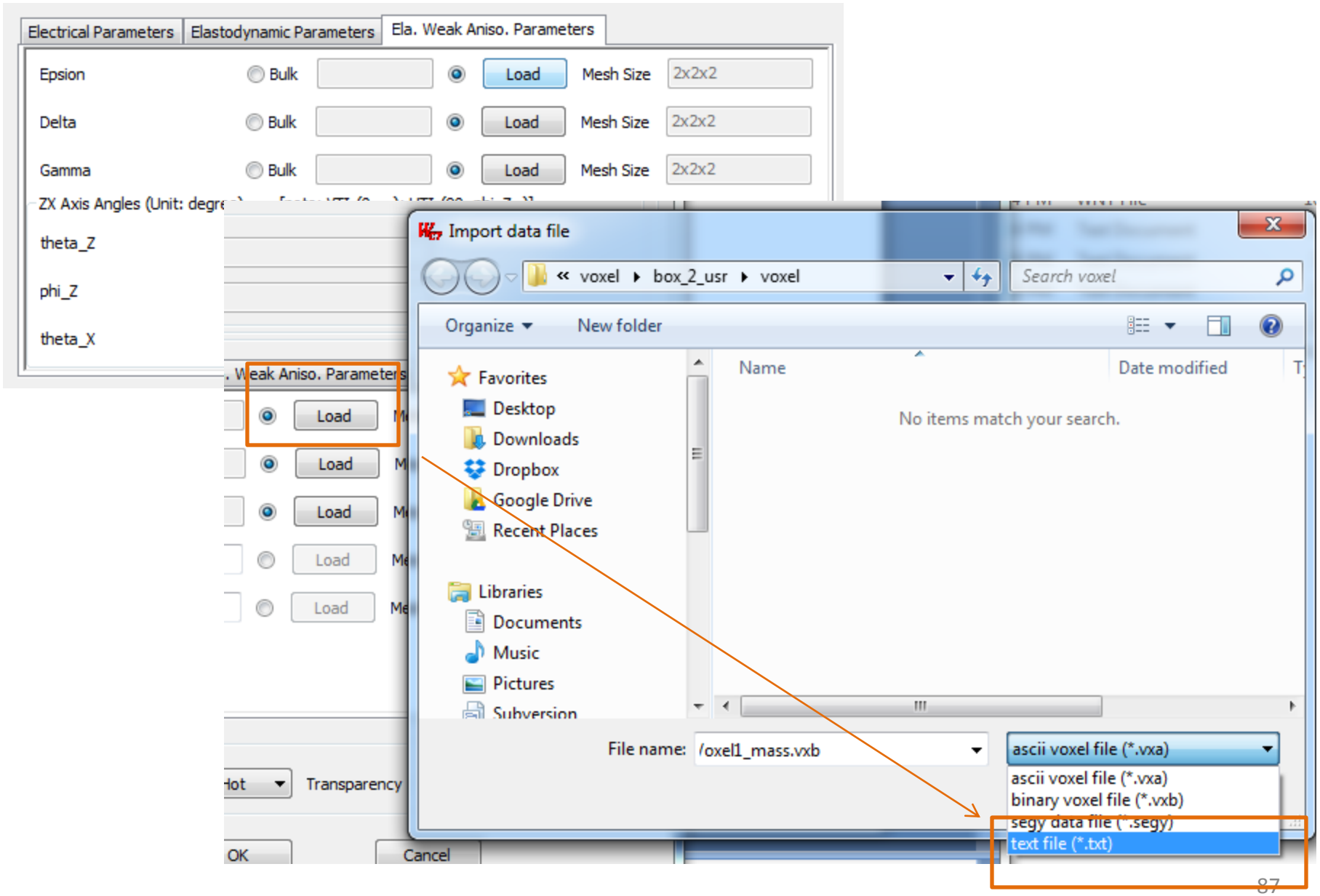
Skip page: Electrical parameters

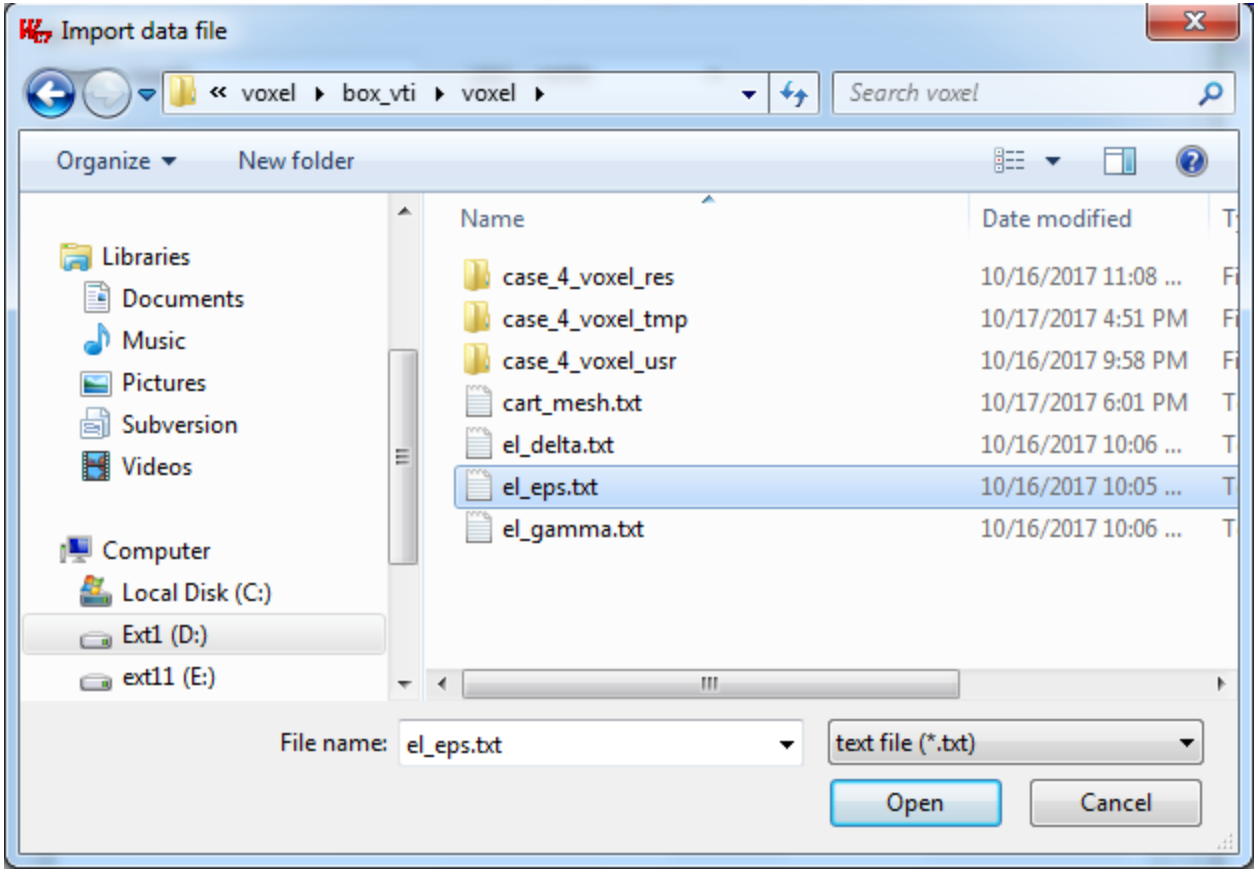
In the Elastodynamic Parameters page, input bulk mass, vp, vs, respectively.

Actually, input for vp & vs can be skipped in this case, because they will not be used in the simulation.

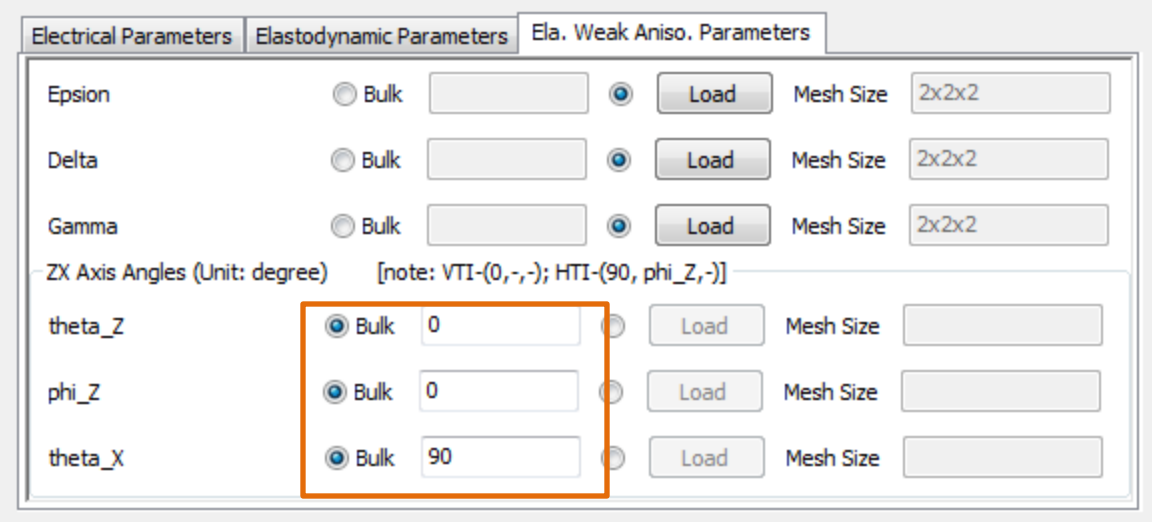


In the Weak Aniso. Parameters page, input bulk mass, vp, vs, respectively.

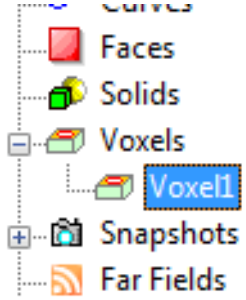



Import data file
« voxel ▸ box_vti ▸ voxel ▸
Search voxel
Organize
New folder
Libraries
Documents
Music
Pictures
Subversion
Videos
Computer
Local Disk (C:)
Ext1 (D:)
ext11 (E:)
Name
Date modified
case_4_voxel_res
10/16/2017 11:08 ...
case_4_voxel_tmp
10/17/2017 4:51 PM
case_4_voxel_usr
10/16/2017 9:58 PM
cart_mesh.txt
10/17/2017 6:01 PM
el_delta.txt
10/16/2017 10:06 ...
el_eps.txt
10/16/2017 10:05 ...
el_gamma.txt
10/16/2017 10:06 ...
File name:
el_eps.txt
text file (*.txt)
Open
Cancel

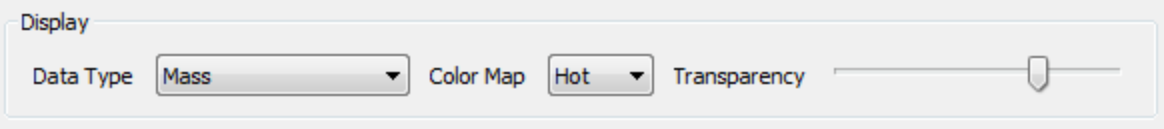
For the material rotation angle, due to it is VTI material, we keep these input as default values: (0, 0, 90º)



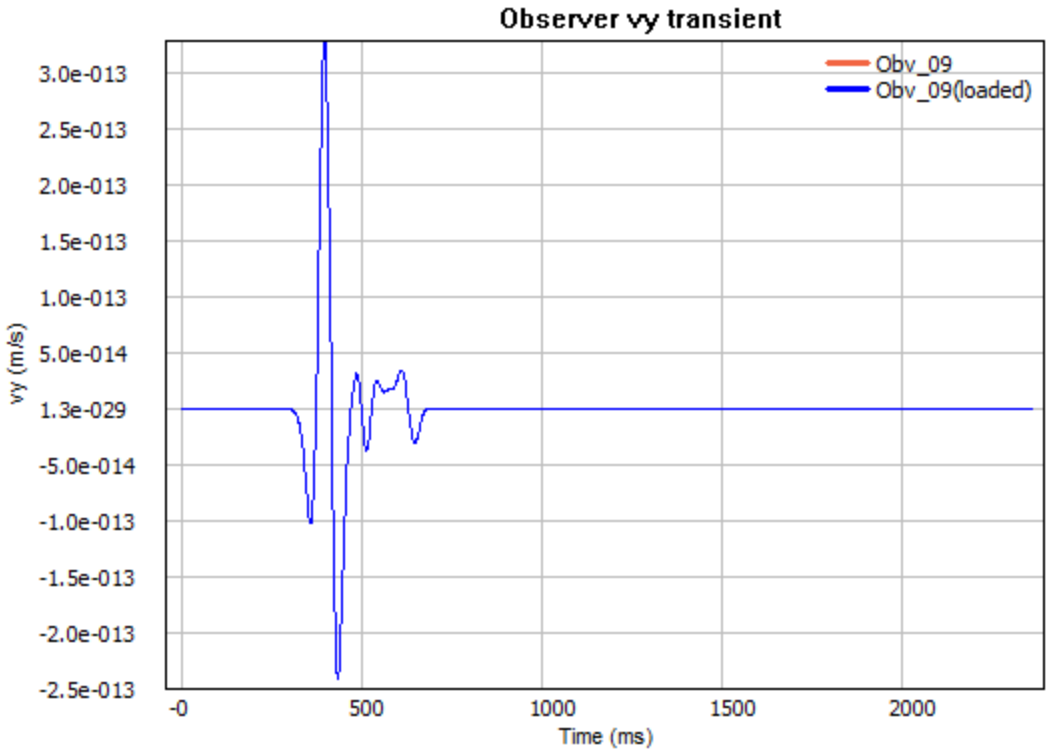
After all voxel parameters are set correctly, then “OK” to add this voxel in the project, as right figure



After data files are defined, let the GUI show the Mass in the voxel region, setup the transparency also, as following.



Then we can simulate this project, and compare the simulation result with a regular box setting. We can see two sets of data overlap.

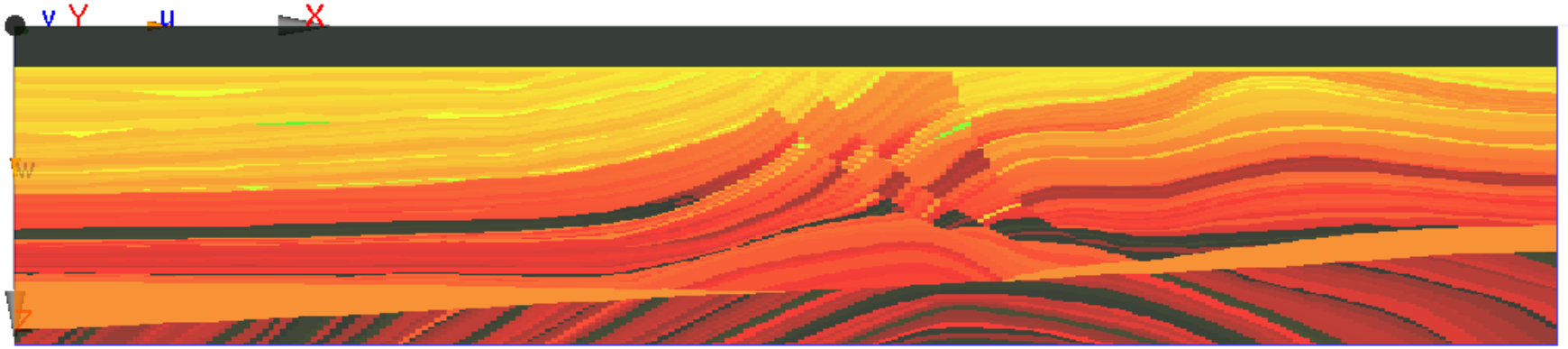


Voxel

Regular box

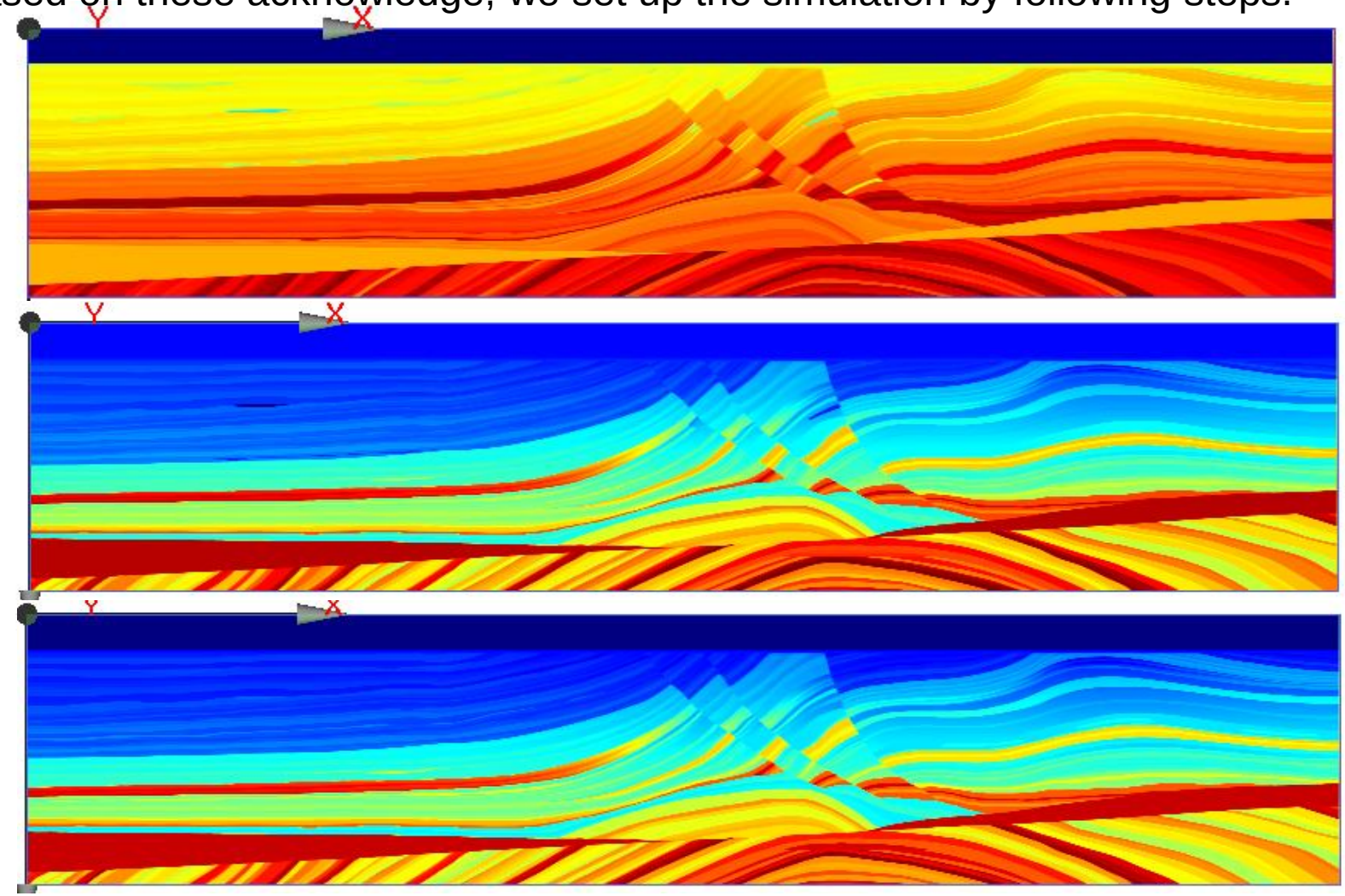
Case (3) Simulation on 2D Marmousi II model

This case simulates the Marmousi ii model, to show how the wave propagate in the computational domain by snapshot



Marmousi ii dataset

The Marmousi ii dataset used in the simulation include mass, vp and vs properties. All are imported from segy files.
The resolution of dataset is 1.25m in x, y and z. The cell number is 13601*x*1*x*2801.
Based on these acknowledge, we set up the simulation by following steps.

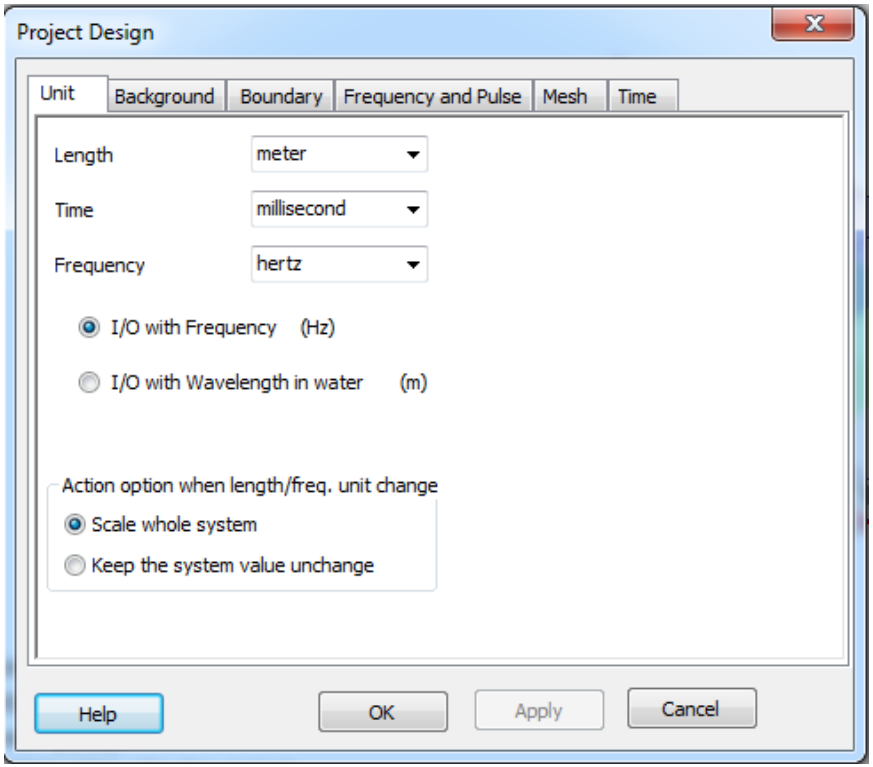


Case setup: Materials

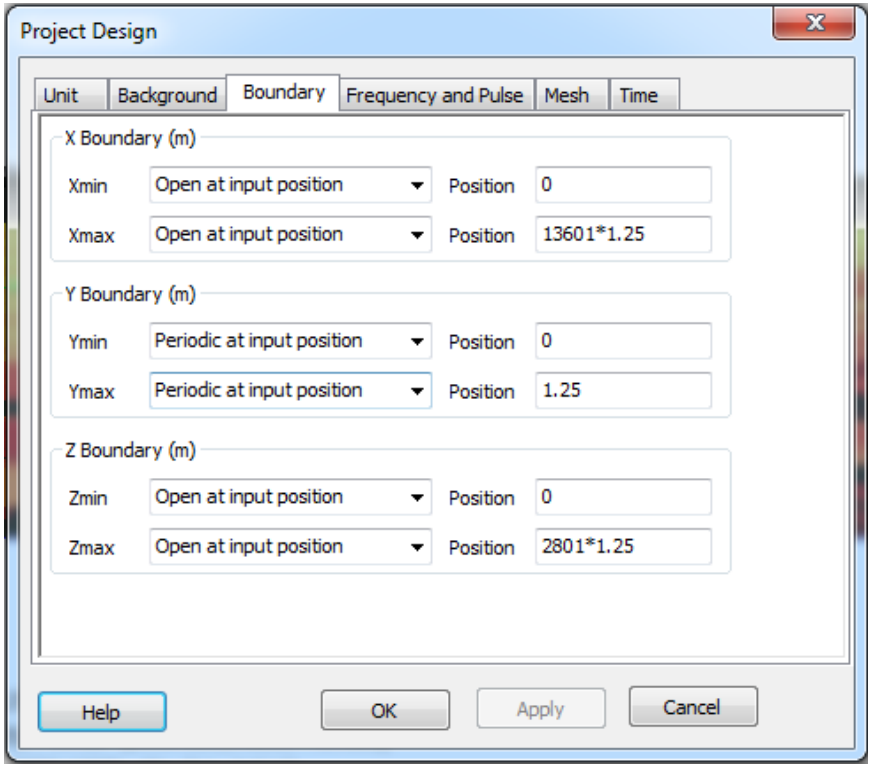
In this simulation, the whole computational domain will be occupied by Marmousi II model. So, we don’t need to setup any addition material, just let the project use the default material.

Case setup

Project setting: unit

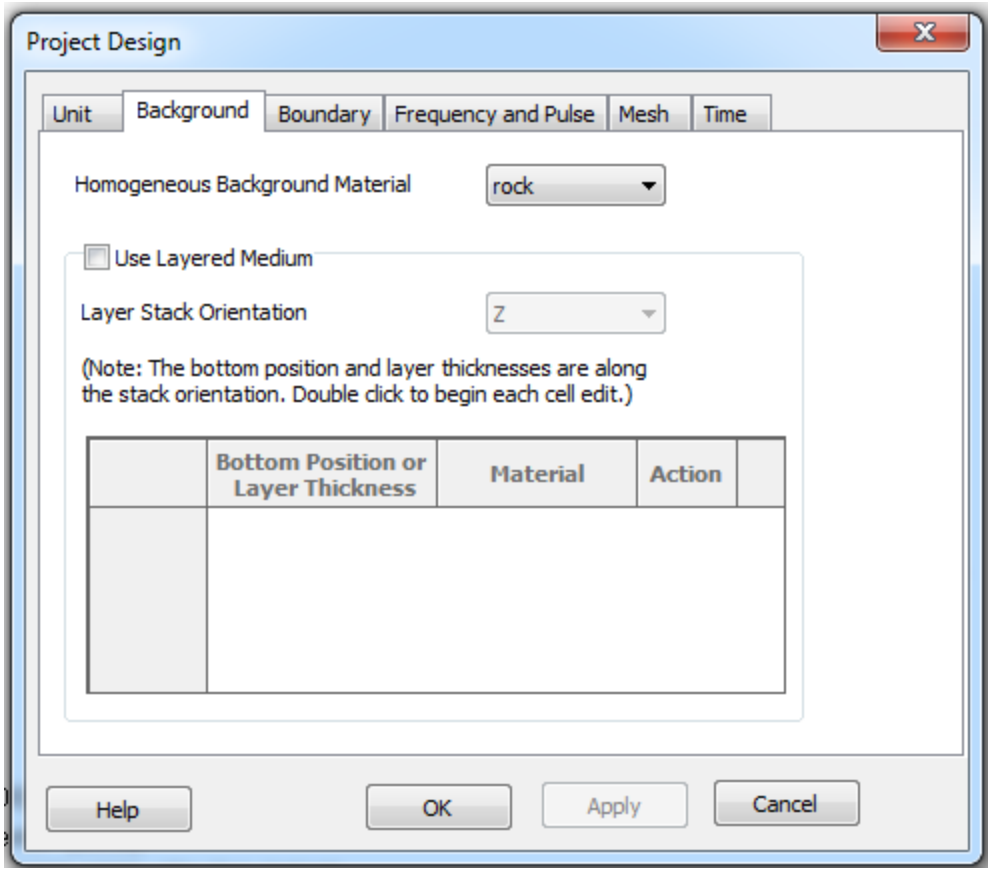


Project size & B.C.

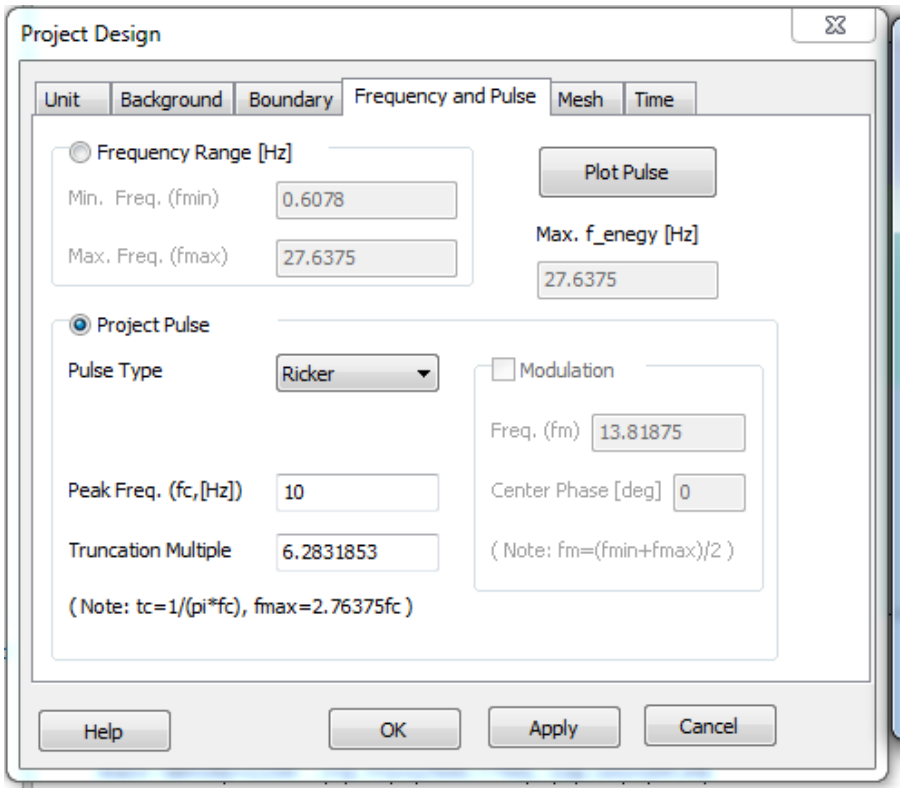


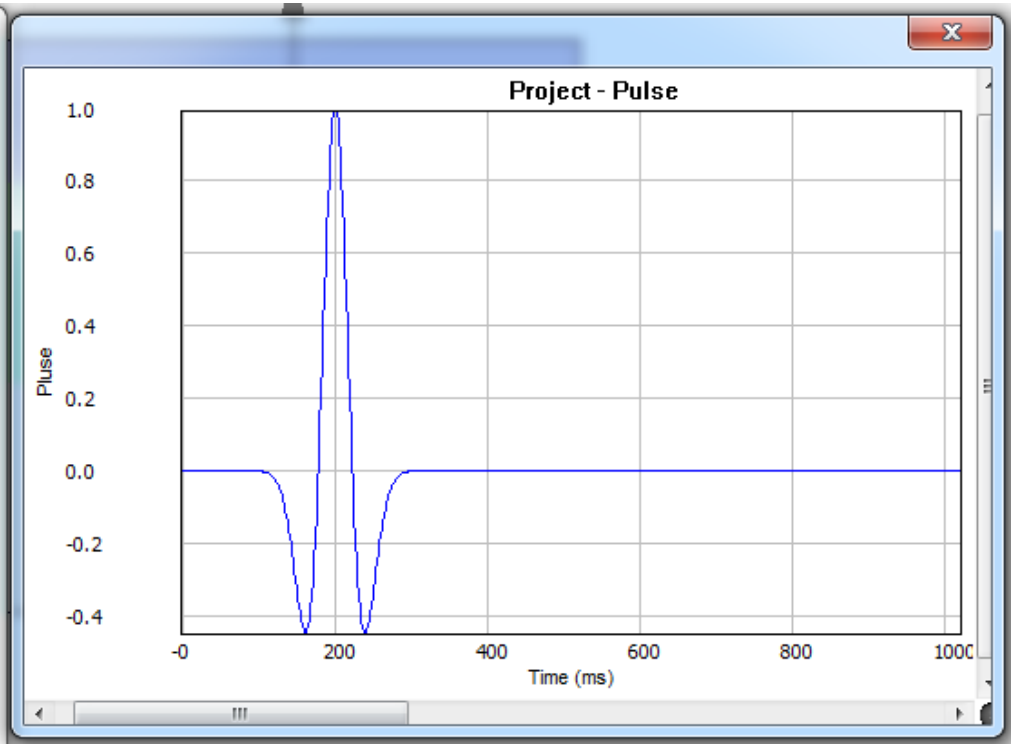
Set project size as: (13601*1.25, 1.25, 2801*1.25)

Project background



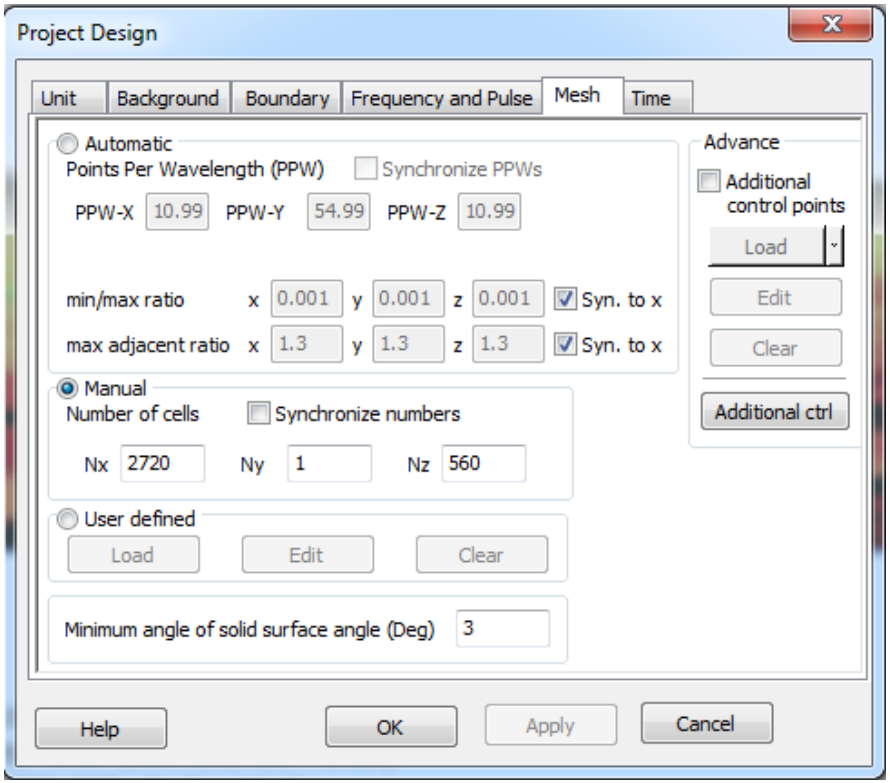
Project pulse: f_c=10 Hz Ricker wave

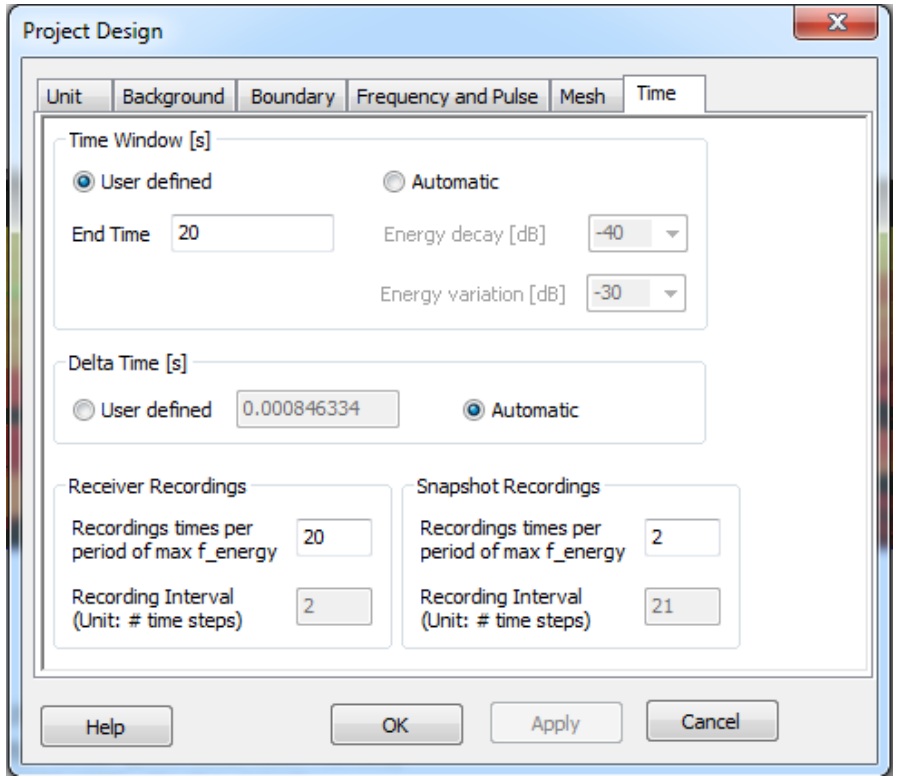




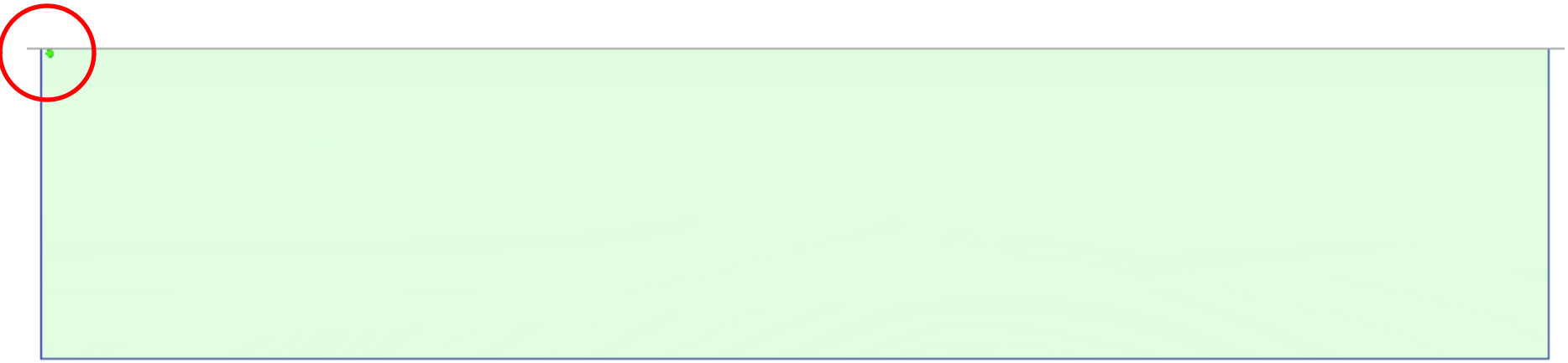
Project mesh: 2720x1x560, so, we can make sure the FDTD sampling density is bigger than 10 points per wave length

Project time setting: 20s time window & automatic Δt. Snapshot recording interval is 2 points per period.



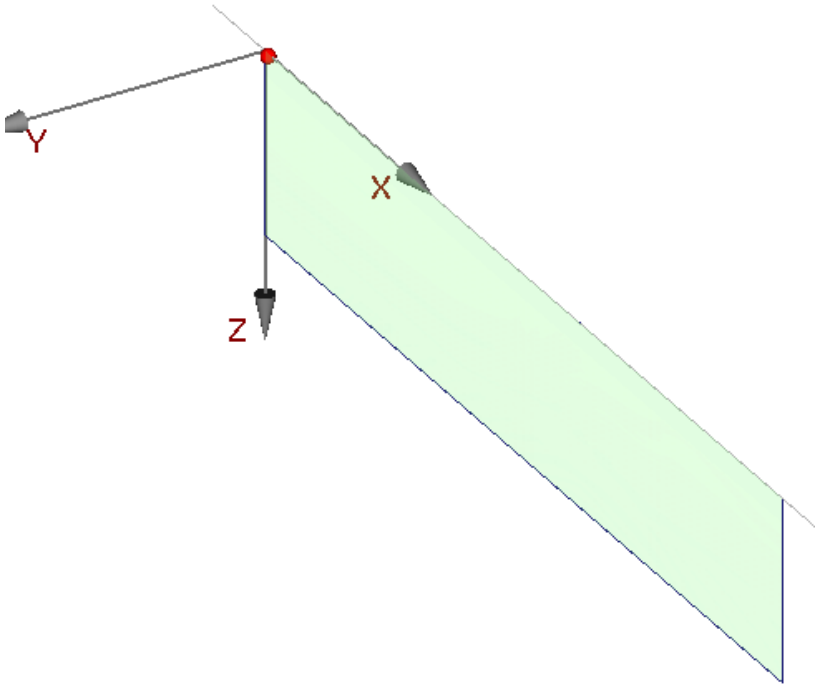


Source: point monopole source at (100, 0.625, 50)

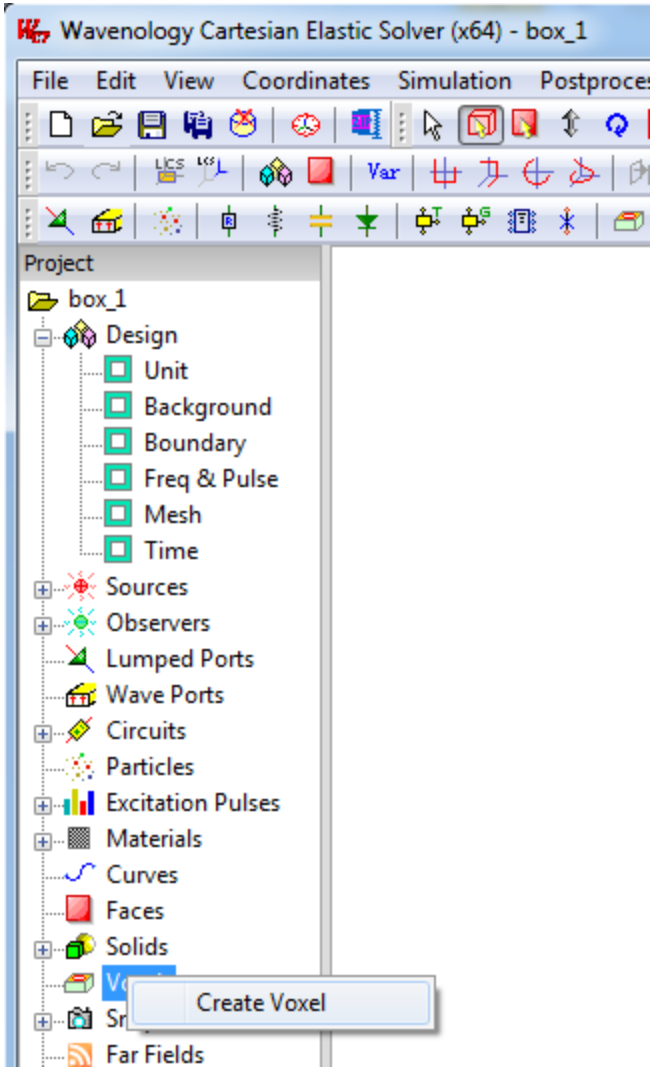


There is not receiver in this case, we will use snapshot to check the field propagation.

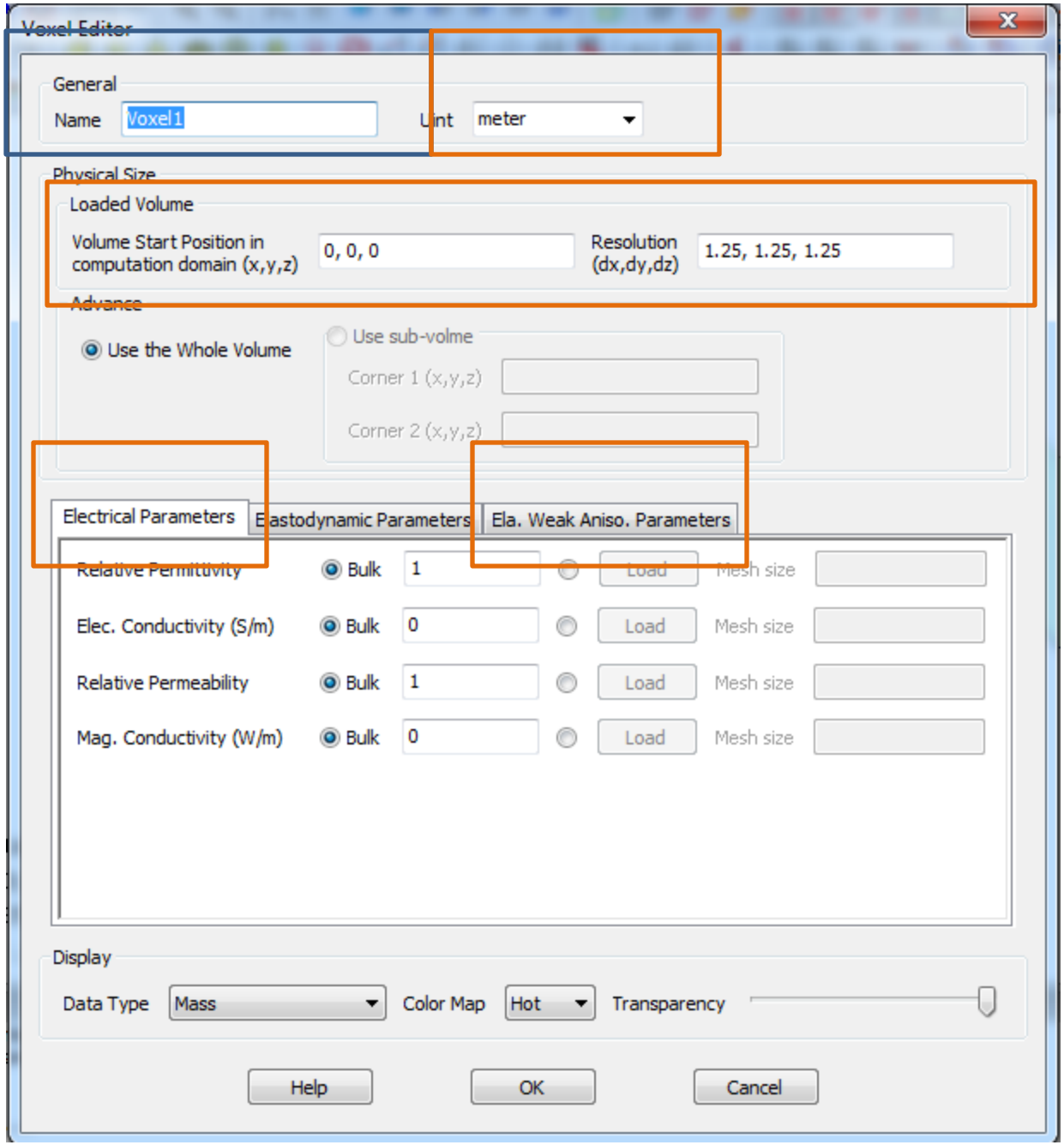
After project setup, source and voxel data files are ready, we can see the project as following



Then, create voxel



Voxel name

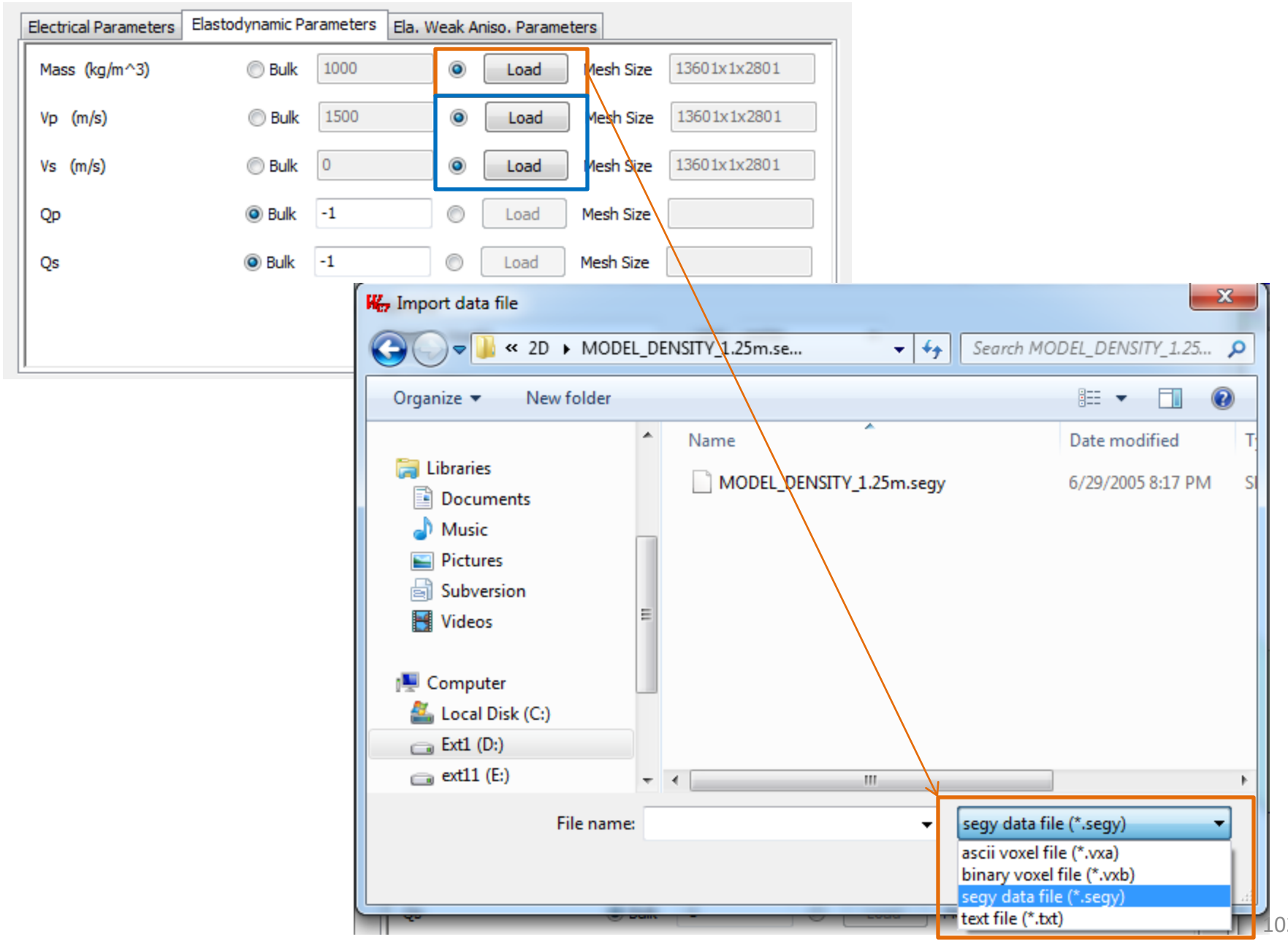


Voxel unit

Voxel start position & resolution

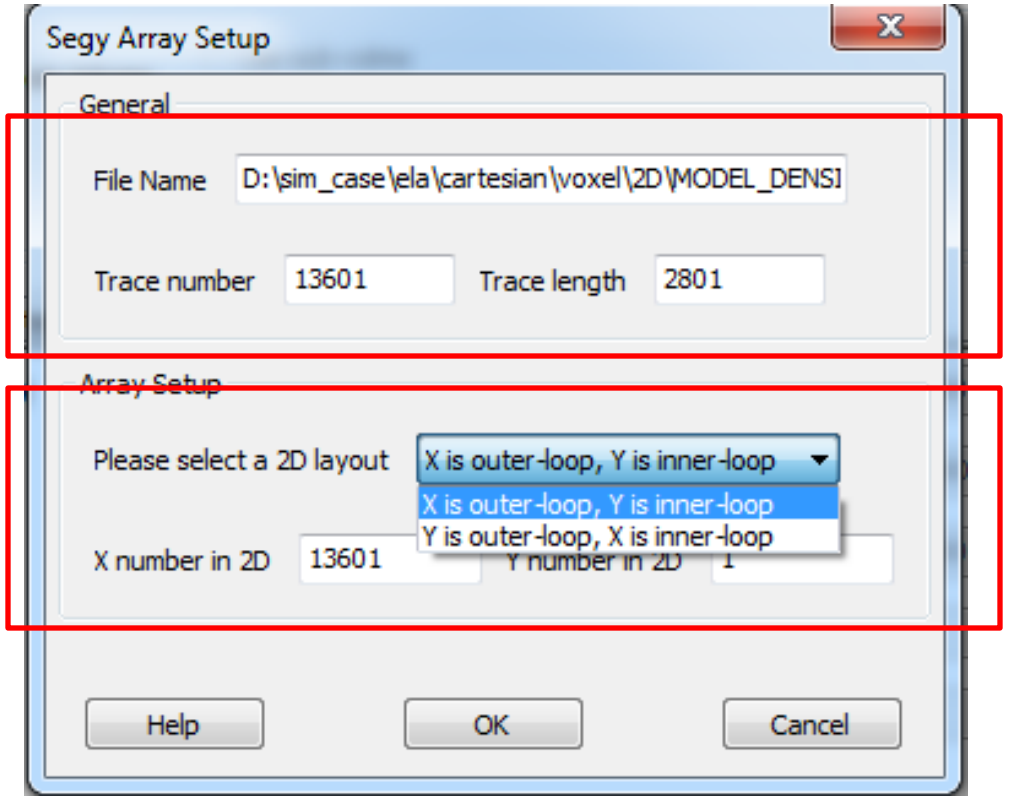
Skip pages: Electrical parameters & Ela. Weak Aniso. Parameters

In the Elastodynamic Parameters page, load mass, vp, vs from SEGY data files, respectively.



In a SEGY data file, there are N traces with a length of M. We will treat M as the number of cell in Z direction. N traces will be with a 2D layout in X-Y plane as nX*nY traces.

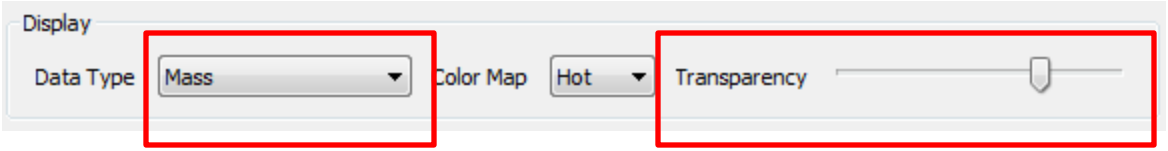
User need to define how to organize the X-Y layout.



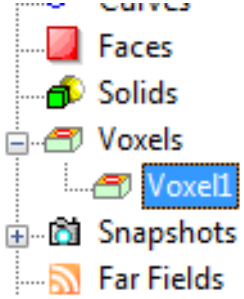
Data & file information

X-Y layout setup

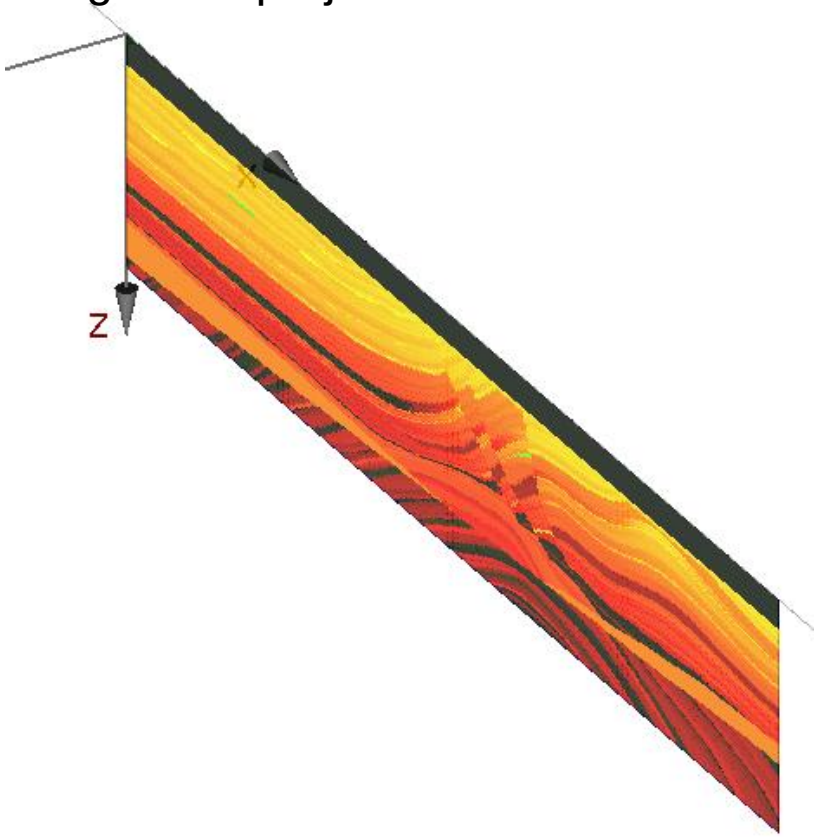
After data files are defined, let the GUI show the Mass in the voxel region, setup the transparency also, as following.

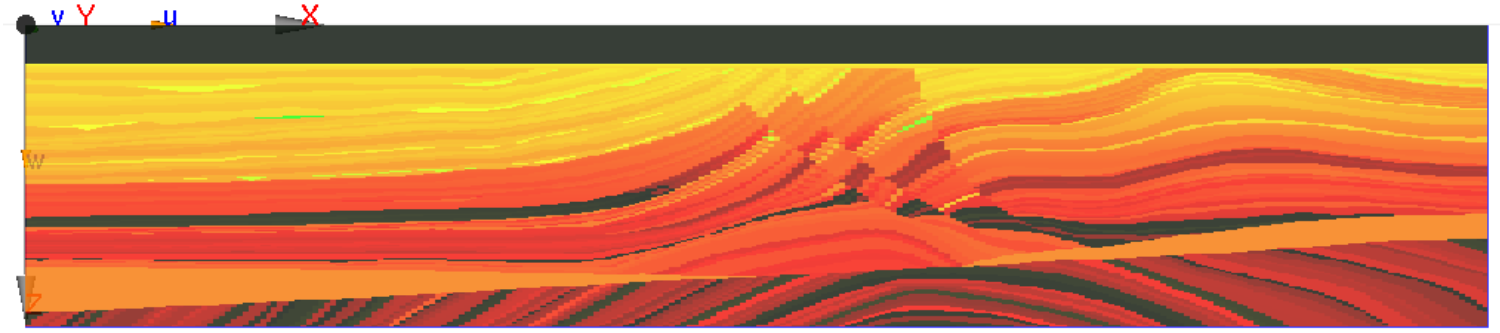


After all voxel parameters are set correctly, then “OK” to add this voxel in the project, as right figure



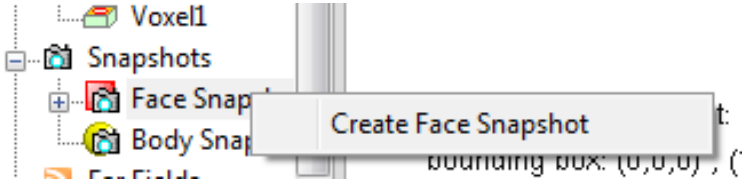
Following is the project in GUI after voxel is set.



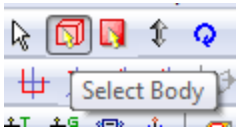


Then, set up a 2D snapshot to capture the field

Right click on treenode: “Snapshot->Facesnapshot” to “Create Face Snapshot”



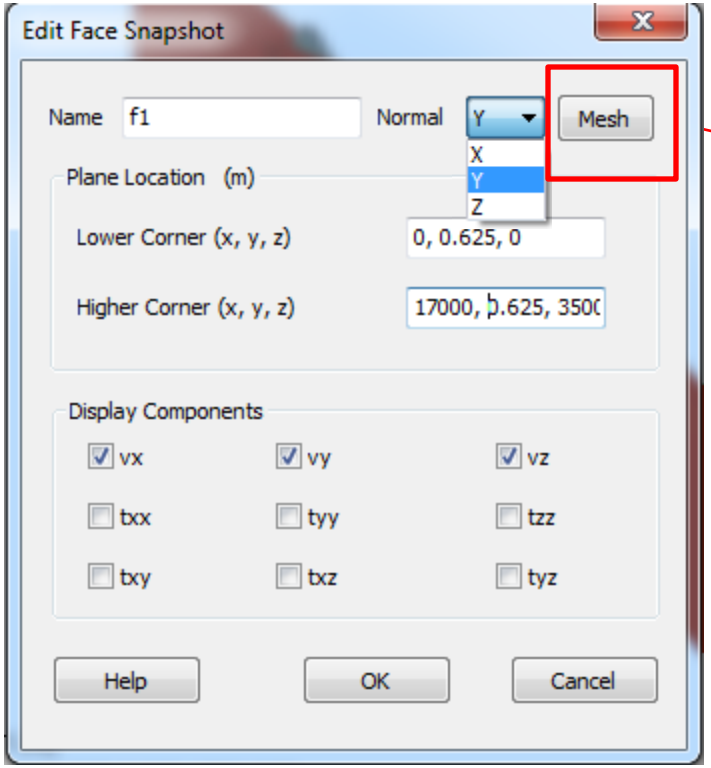
If you find the menu “Create Face Snapshot” is disabled (gray), please make sure the GUI is in the “Select Body” mode.

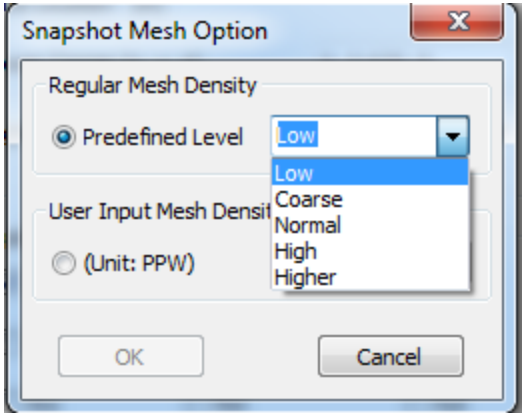


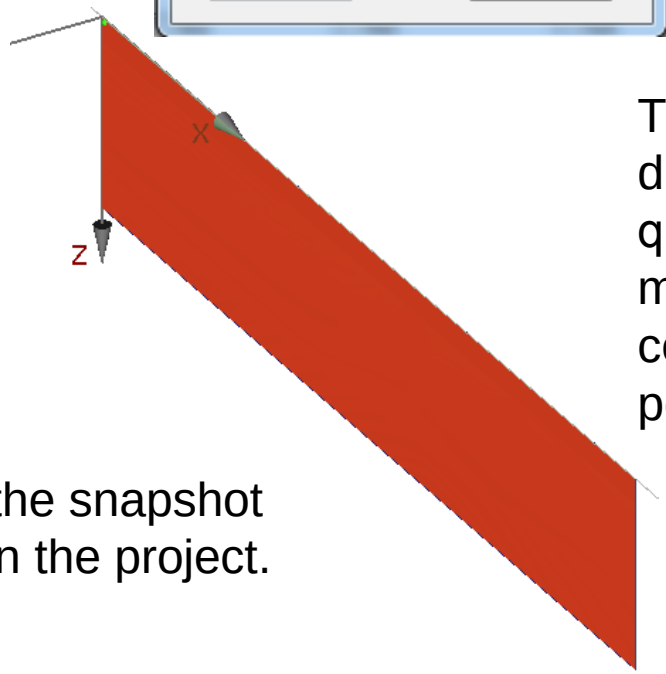
And then click on 3D canvas once, then popup this “Create Face Snapshot” menu again, it will be enabled.

Set up this snapshot in the Y center of domain, and capture all velocity components

Due to this snapshot covers the whole computational domain, the data in snapshot will be very large, we need to use ***low*** quality discretization for this snapshot



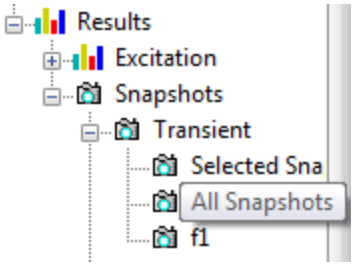




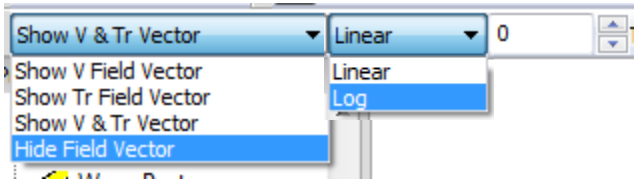
The default discretization quality is "***Normal***", means that each cell has one sample point.

This is the snapshot region in the project.

Then we can simulate this project.
Following is the simulation result in the snapshot.



Hide field vector & use ***log*** mode



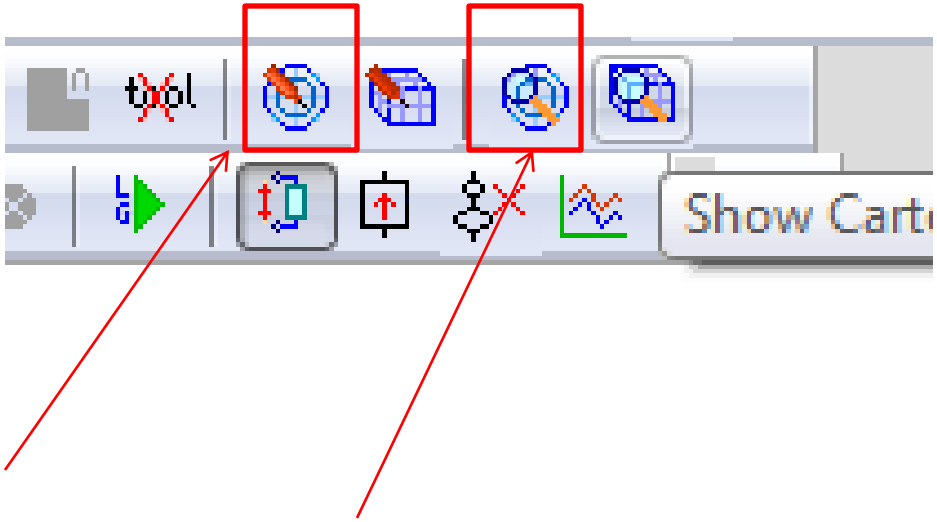
How to set up the displaying control, please refer to here.

frame: 60

frame: 120

frame: 180

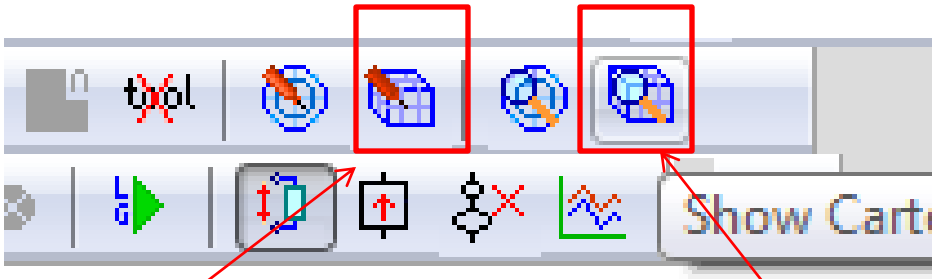
Generate Mesh Files from Wavenology Mesher



Generate Cylindrical mesh

View Cylindrical mesh

Note: for Cylindrical mesh, please refer to Wavenology BHA manual



Generate Cartesian mesh for **whole simulation space**, data files as following:

cart_mesh.txt cell material index, ascii format
material_info.txt material name and index , ascii format
cart_mesh_grid.m grid position, matlab m file

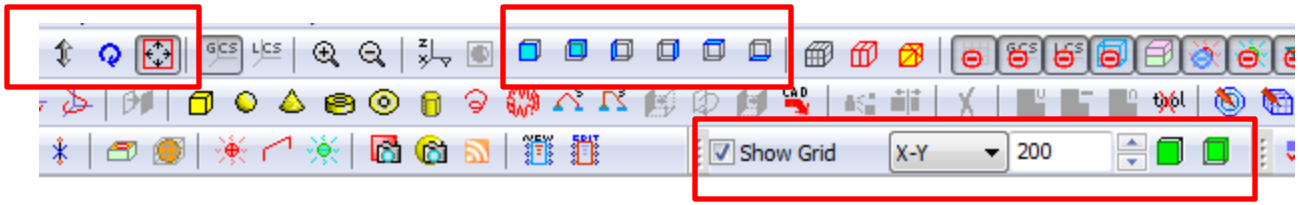
View Cartesian mesh

It will enter a 3D mesh view mode, which provides a functionality to export 2D/3D sub-volume mesh from the whole mesh

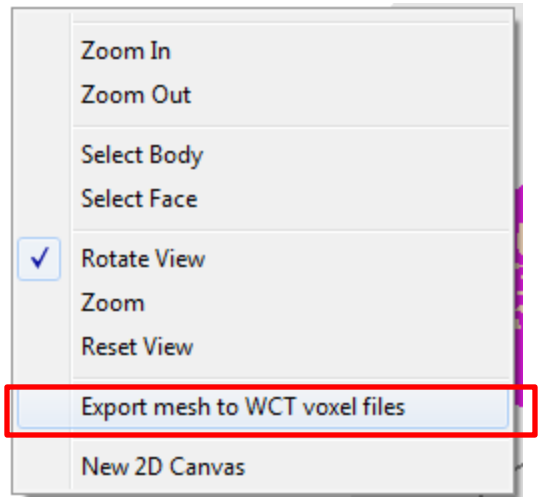
In the 3D mesh view mode

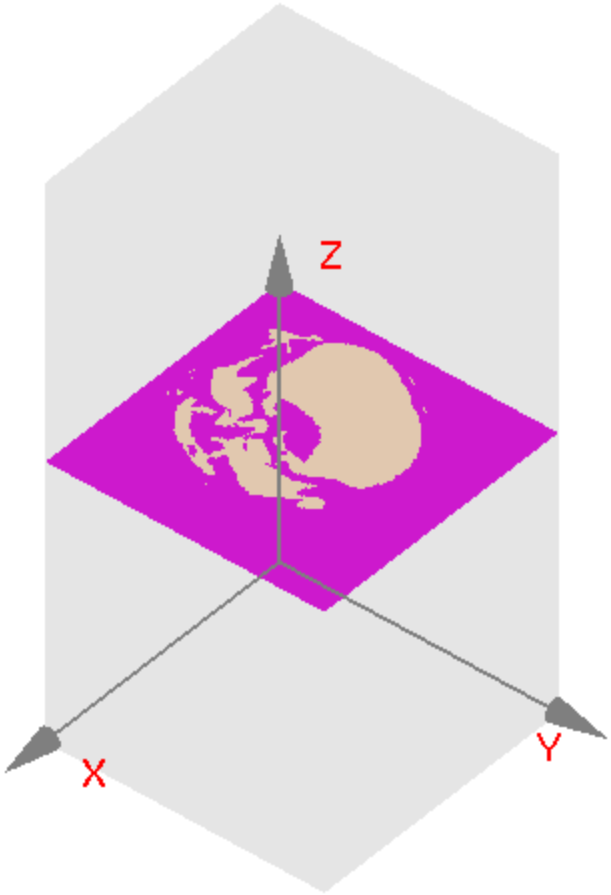
Mouse mode

View angle

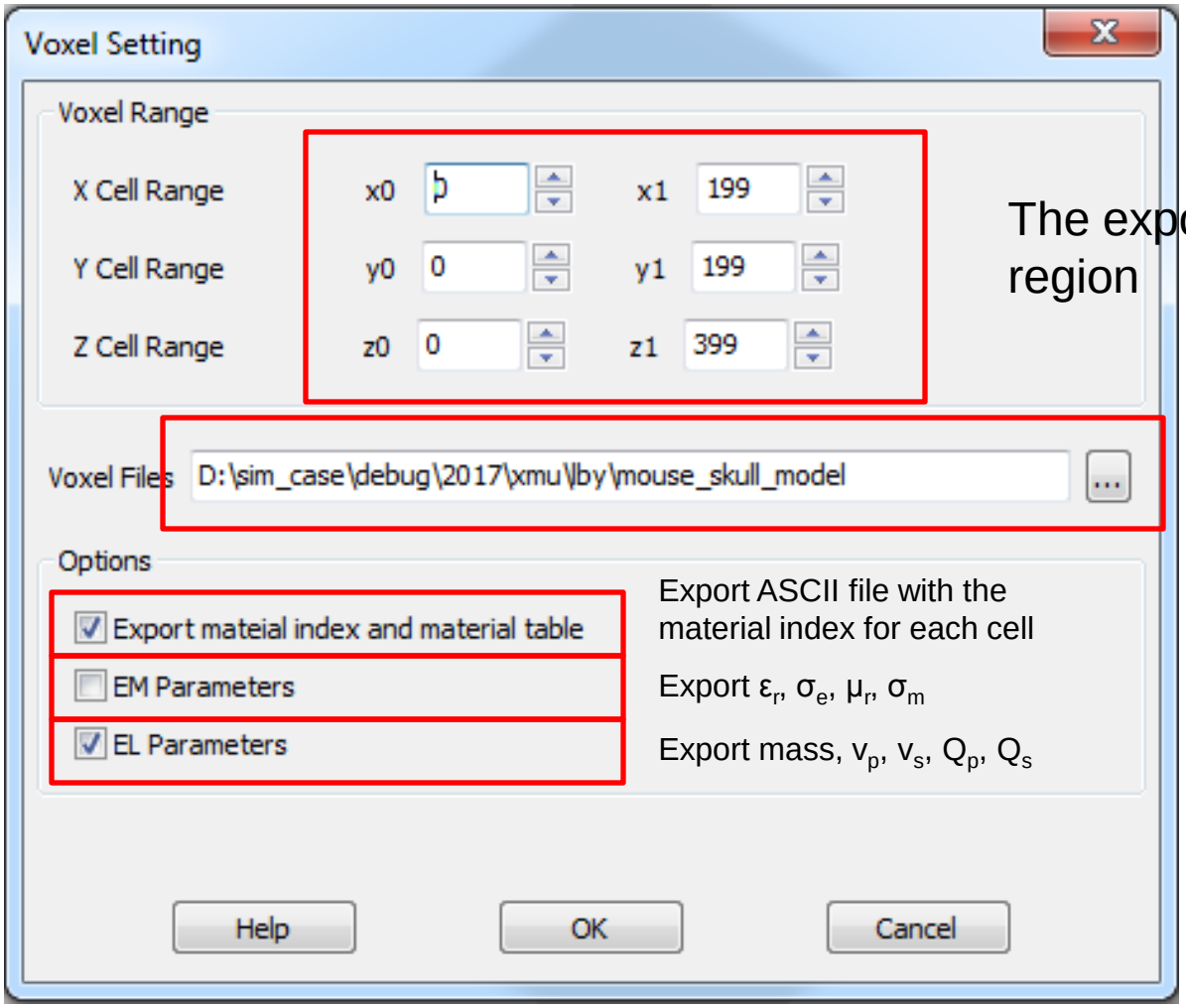


Cross-section control





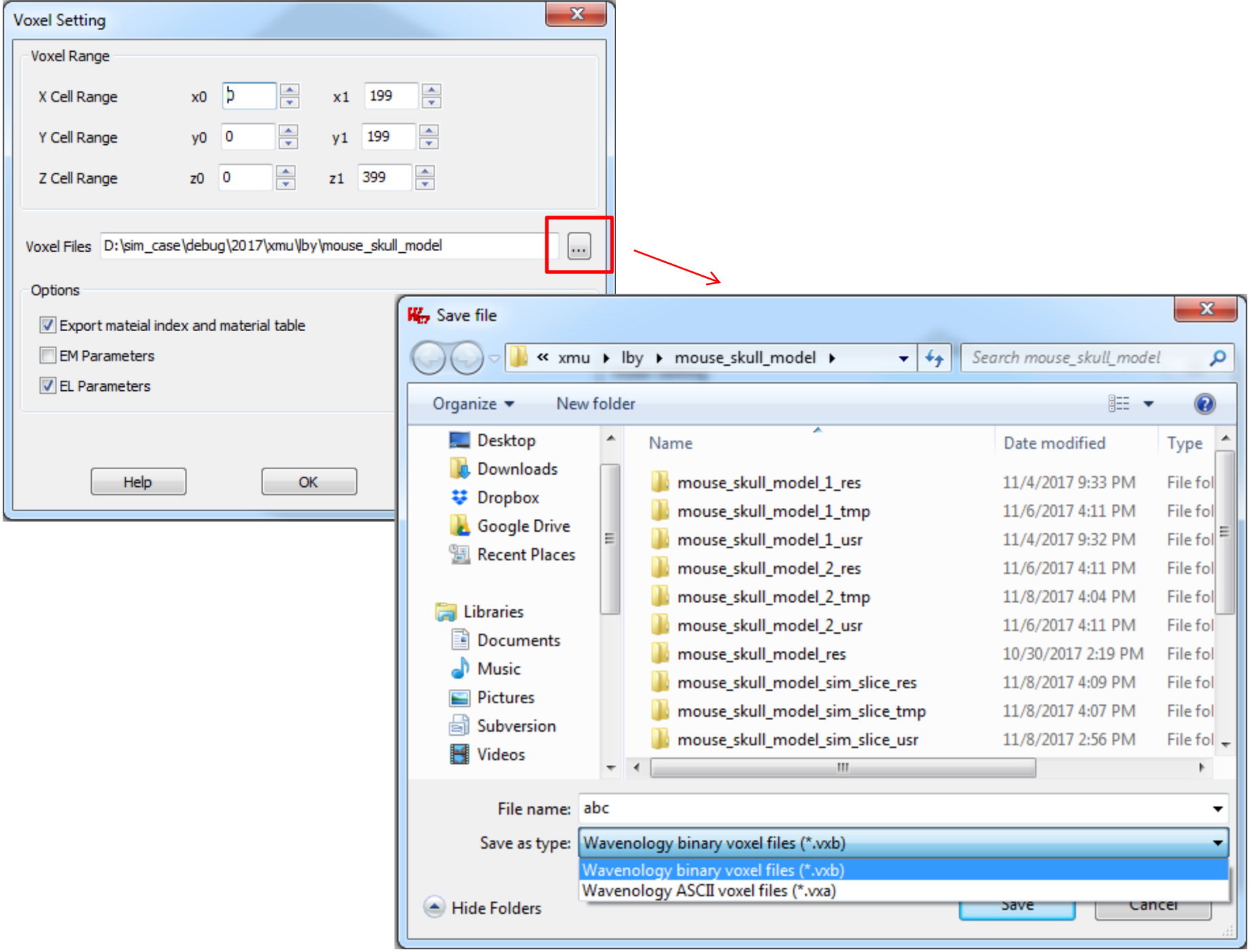
Right click on this canvas, a menu with "**Export mesh to WCT voxel files**" item will appear



The exported region

The target folder with the root of file name for exported files.

The voxel data file will be “vxb” or “vxa” only


Voxel Setting
Voxel Range
X Cell Range
x0
0
x1
199
Y Cell Range
y0
0
y1
199
Z Cell Range
z0
0
z1
399
Voxel Files
D:\sim_case\debug\2017\xmu\lby\mouse_skull_model
...
Options
Export mateial index and material table
EM Parameters
EL Parameters
Help
OK
Save file
« xmu ▸ lby ▸ mouse_skull_model ▸
Search mouse_skull_model
Organize
New folder
Desktop
Downloads
Dropbox
Google Drive
Recent Places
Libraries
Documents
Music
Pictures
Subversion
Videos
Name
Date modified
Type
mouse_skull_model_1_res 11/4/2017 9:33 PM File fol
mouse_skull_model_1_tmp 11/6/2017 4:11 PM File fol
mouse_skull_model_1_usr 11/4/2017 9:32 PM File fol
mouse_skull_model_2_res 11/6/2017 4:11 PM File fol
mouse_skull_model_2_tmp 11/8/2017 4:04 PM File fol
mouse_skull_model_2_usr 11/6/2017 4:11 PM File fol
mouse_skull_model_res 10/30/2017 2:19 PM File fol
mouse_skull_model_sim_slice_res 11/8/2017 4:09 PM File fol
mouse_skull_model_sim_slice_tmp 11/8/2017 4:07 PM File fol
mouse_skull_model_sim_slice_usr 11/8/2017 2:56 PM File fol
File name: abc
Save as type: Wavenology binary voxel files (*.vxb)
Wavenology binary voxel files (*.vxb)
Wavenology ASCII voxel files (*.vxa)
Hide Folders
Save
Cancel

Data Files and Format

- The ASCII files with the material index for each cell
  - this option will export 2 files
    1. xxx_Imat.txt : mesh file
    2. xxx_material.txt : a table with material parameters

An example of “xxx_material.txt”

Note: the index start from 0

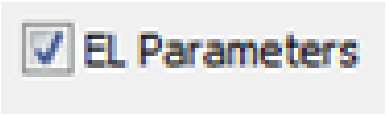
% id	name	eps_r	e_cond	mu_r	m_cond	mass_density	Vp	Vs	
0	Water	78	0	1	0	1000	1500	0	
1	Steel	1	0	1000	0	7890	5790	3235	
2	Bone	1	0	1	0	1700	4800	1400	

An example of “xxx_Imat.txt”

```
% Wavenology Imat file, version 1.0
% nx
20
% ny
10
% nz
6
% material index for each cell, for-loop as:
% for x
%     for y
%         for z
0
0
0
0
0
0
0
0
0
0
0
0
```

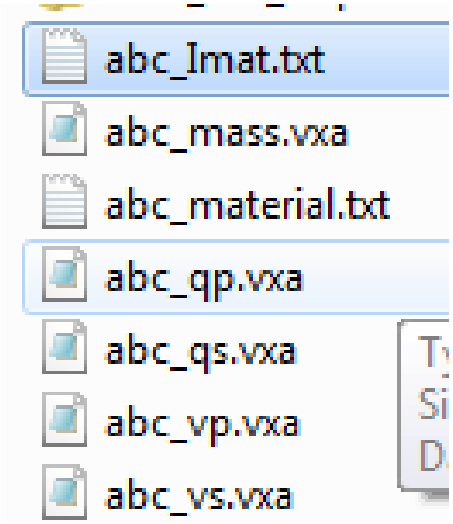
Note: the material index start from 0

- Export 4 data files for EM parameters
  1. xxx_eps_r.vxb/vxa : voxel data file for relative permittivity
  2. xxx_sigma_e.vxb/vxa : voxel data file for electrical conductivity
  3. xxx_mu_r.vxb/vxa : voxel data file for relative permeability
  4. xxx_sigma_m.vxb/vxa : voxel data file for magnetic conductivity



- Export 5 data files for EL parameters
  1. xxx_massvxb/vxa : voxel data file for mass
  2. xxx_vp.vxb/vxa : voxel data file for vp
  3. xxx_vs.vxb/vxa : voxel data file for vs
  4. xxx_qp.vxb/vxa : voxel data file for qp
  5. xxx_qs.vxb/vxa : voxel data file for qs

Following is an example of exported data files



Note for mesh data files

The exported data files only include the material information of each cell. It does not include any grid information and unit. So, with these data files only, whether they are generated from a non-uniform or uniform grid is unknown. User need to obtain more information about grid in using these data files.

In order to make a good mesh data file, it is suggested to use a uniform grid.

Use the Model from Mesh Files

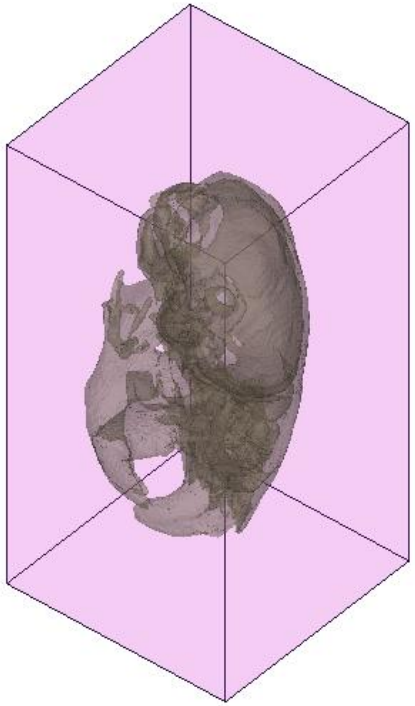
- For **vxa** or **vxb** files, they can be loaded to a voxel

- For **lmat** file, user can use his own code to convert it to **vxa** or **vxb** files with other material property mapping method, then load to a voxel

Demo

Simulate a 2D Slice Cut from a STL model

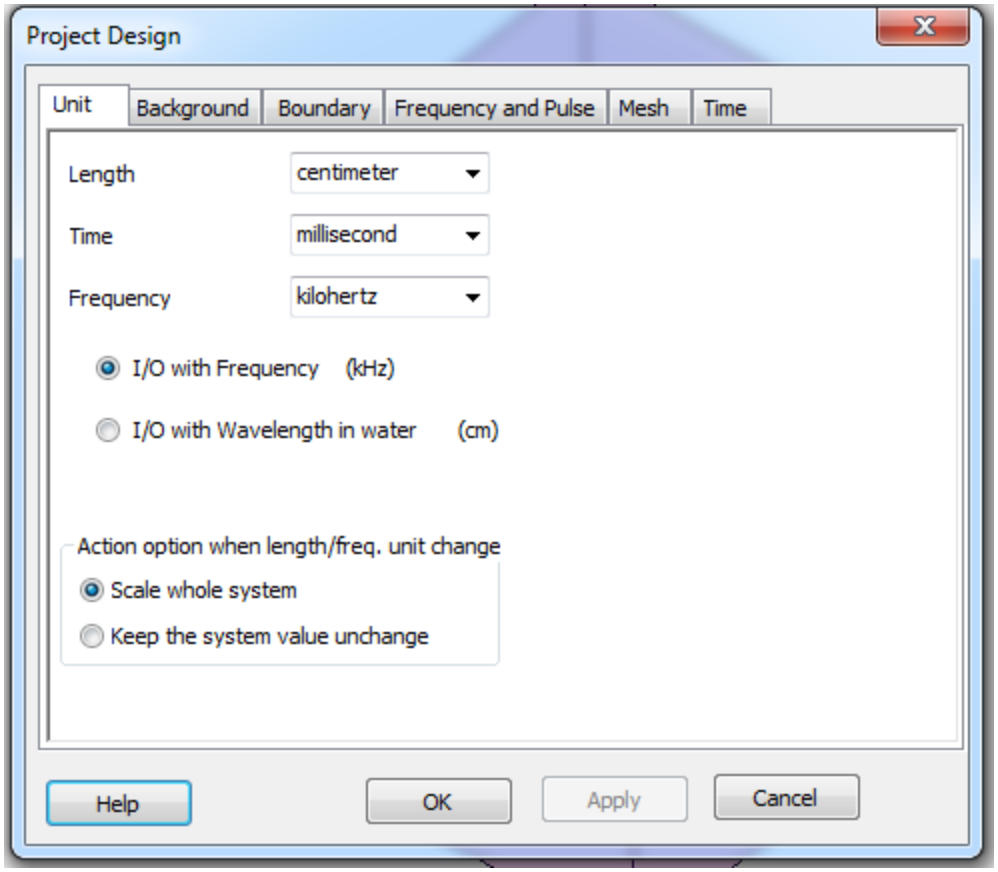
- we have a STL file to describe a mouse skull
- we want to simulate one 2D slice of this model by Cartesian EL solver



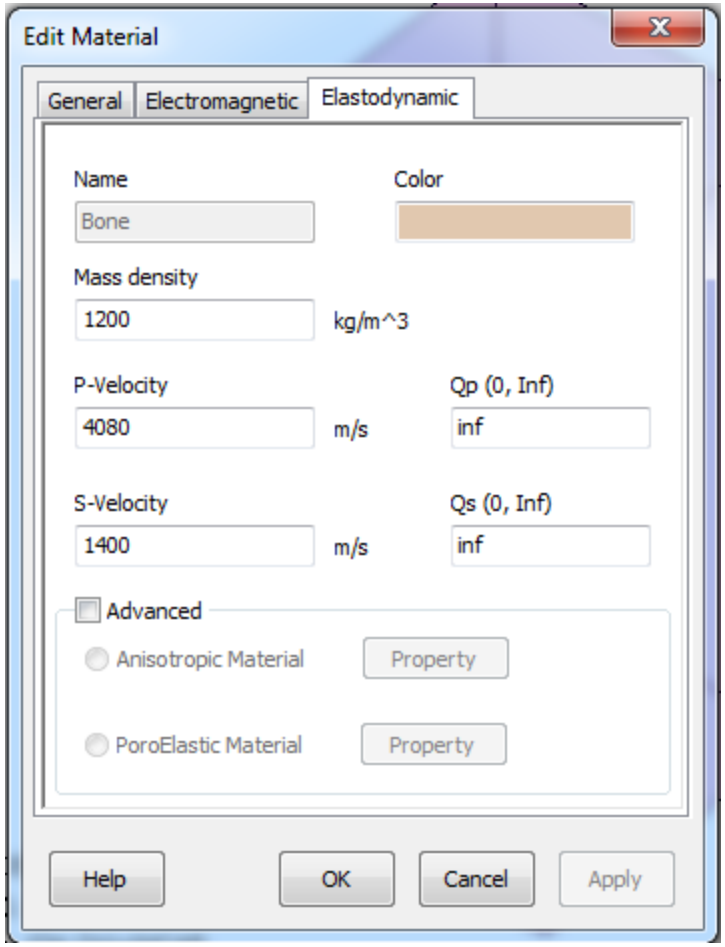
- Due to a STL file can not be guaranteed as a closed 3D solid model. Therefore, it can not be treated as a 3D geometry and be operated by boolean operation. A 2D slice of this model can be only generated by the voxel way.

Step I: use a WCT Cartesian EL project to generate the 2D slice we need

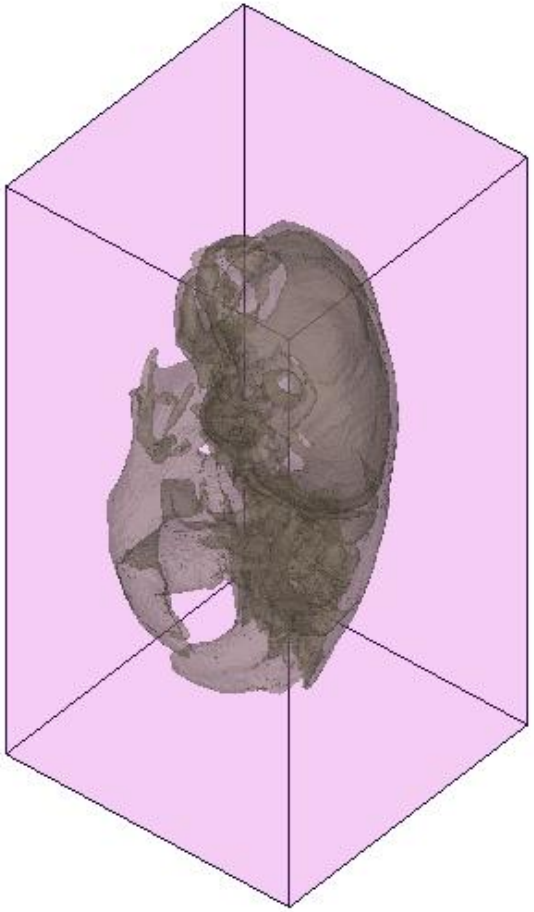
Build a empty Cartesian EL project with **CM** as unit



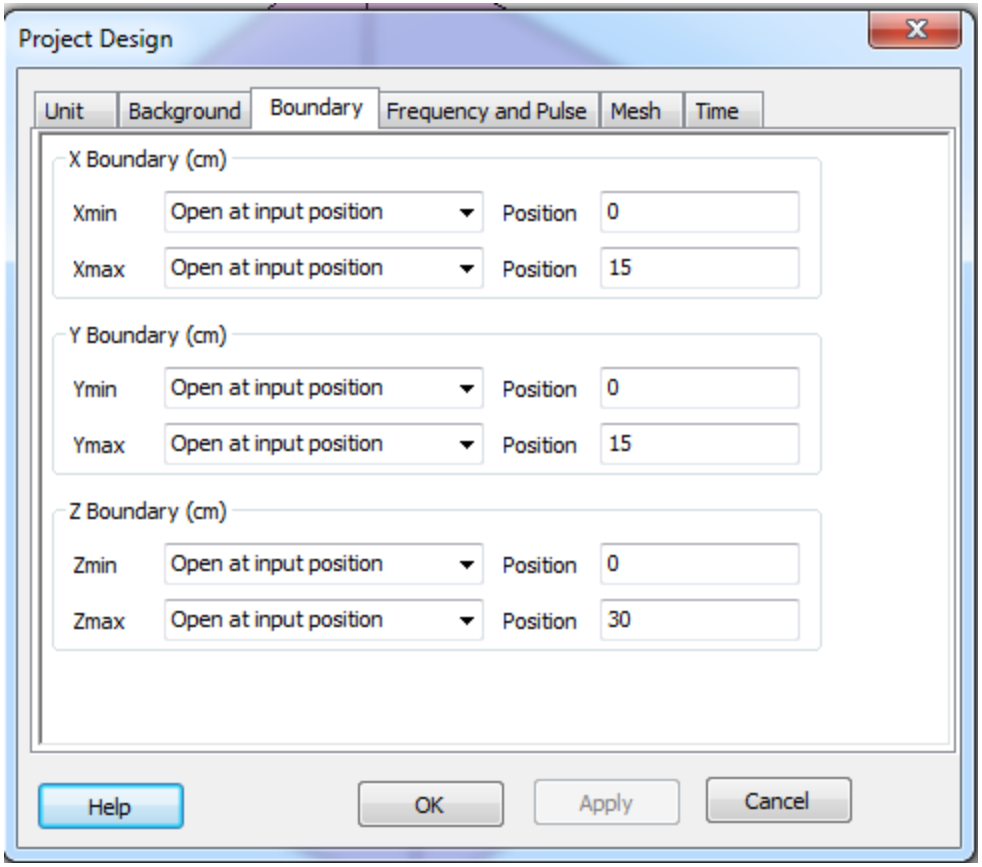
Set project background as **water** and
define a new material: **bone**

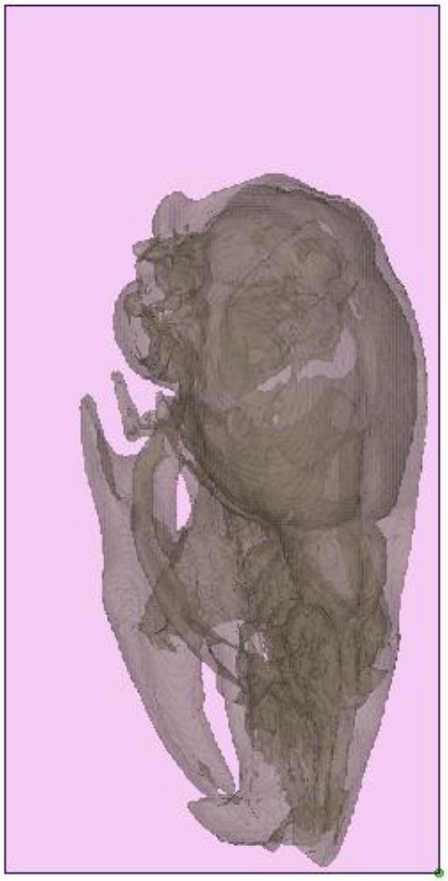


Insert STL model in this project and use material: bone.
Set the model with 50% transparency, it will be looked as,

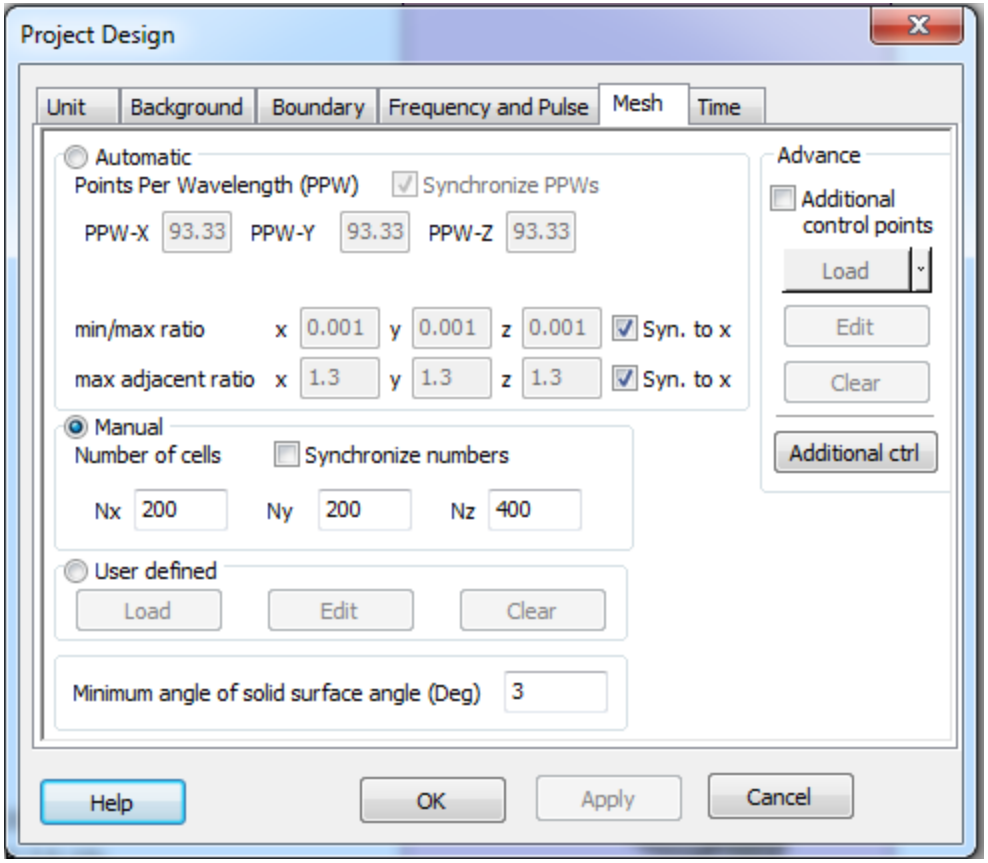


Then we define the domain size as following to close the model

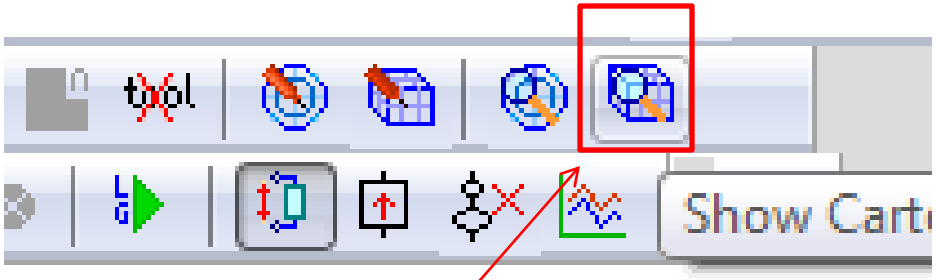




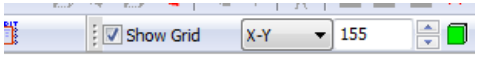
Then set the mesh as a uniform grid as following

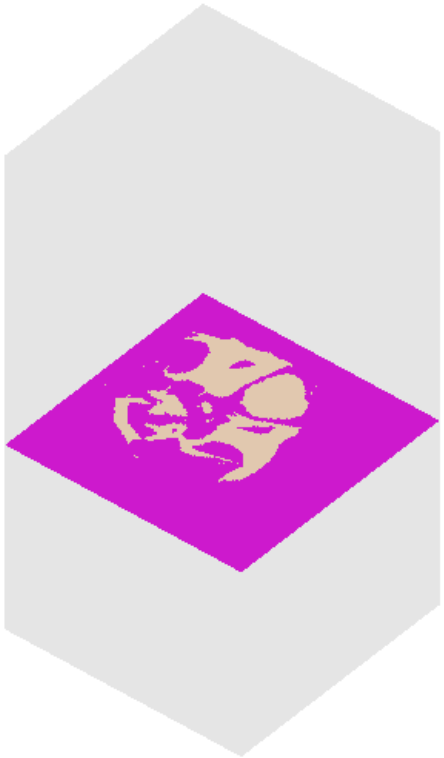


With this setting, we know [Δx, Δy, Δz]=[0.075, 0.075, 0.075] cm

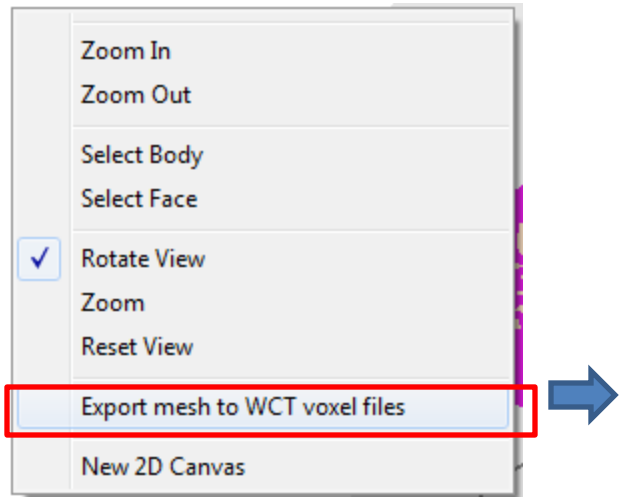


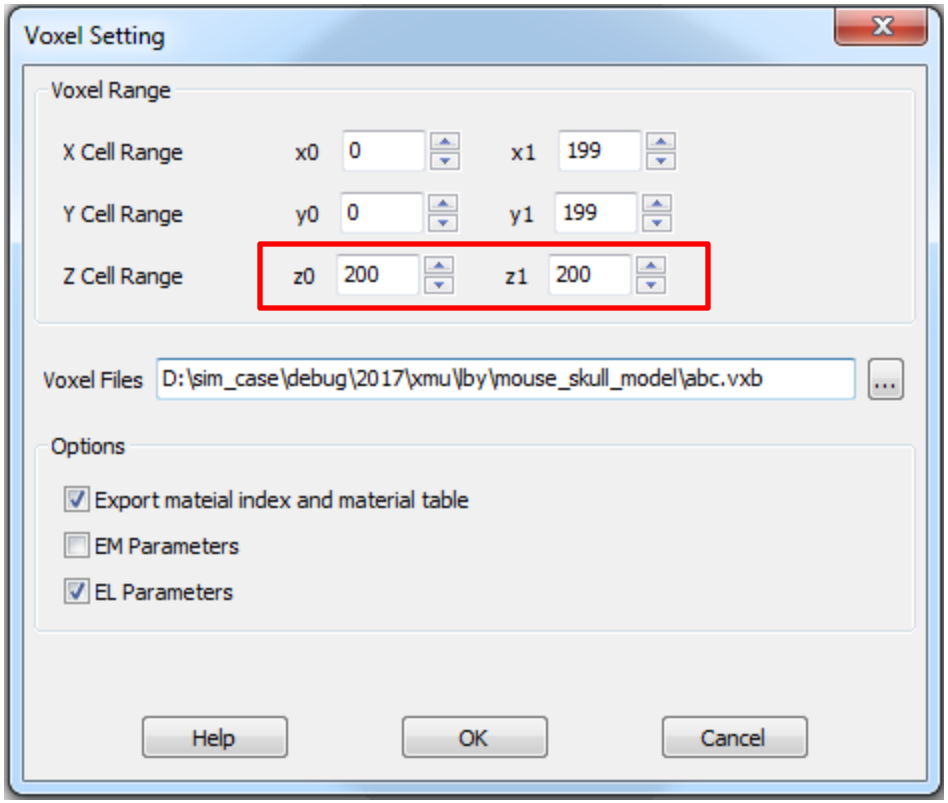
Enter View Cartesian Mesh Mode



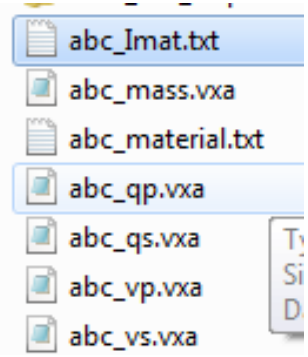


To export the 200th Z slice, which is at Z=15 cm





With data file root name as “abc”, format as vxb, the EL parameter files is

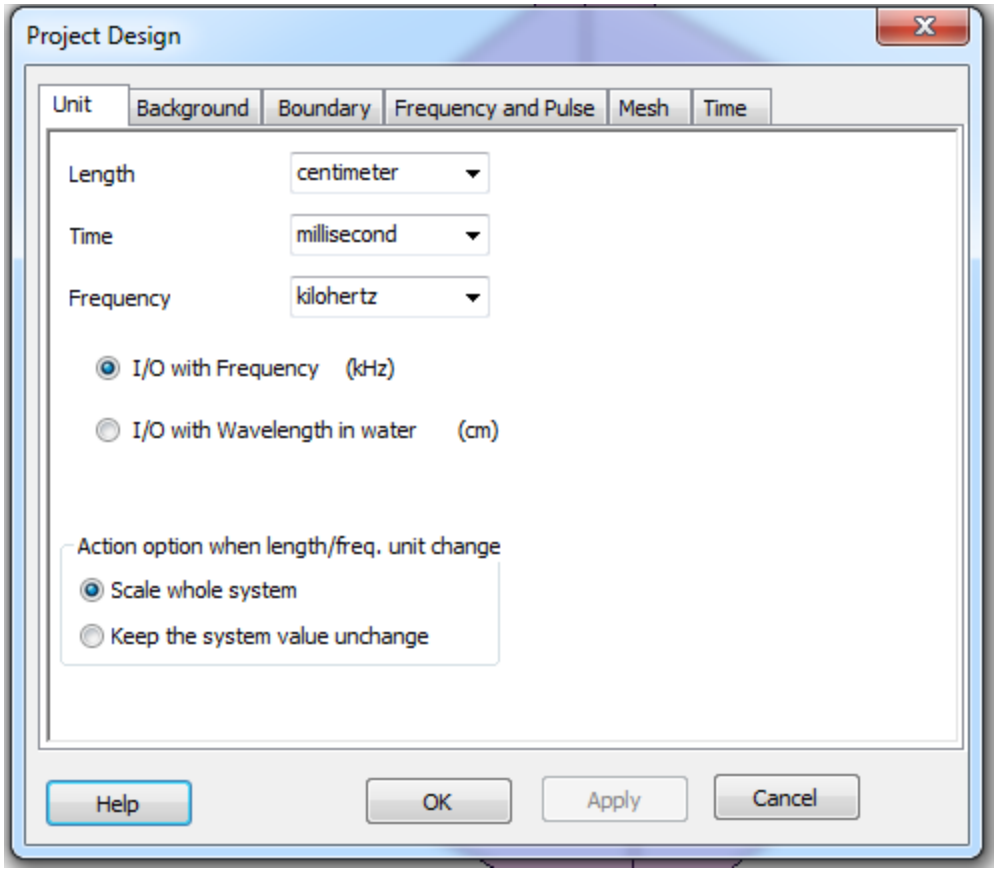


Step II: Insert this 2D slice as voxel in the project we want to simulate

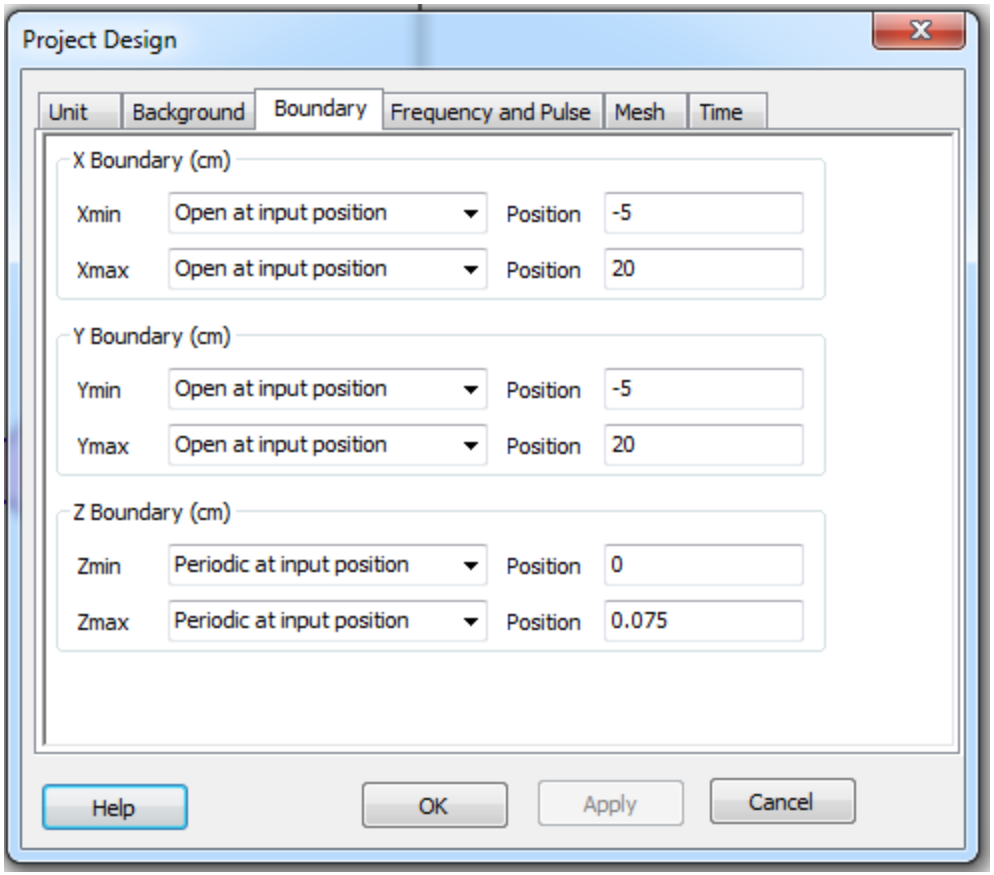
- We know the slice with following information
  - 200x200x1 cells, the cell size is 0.075 cm, both in x, y and z.

  But we can re-scale them in voxel definition.
  - the skull in embedded in water

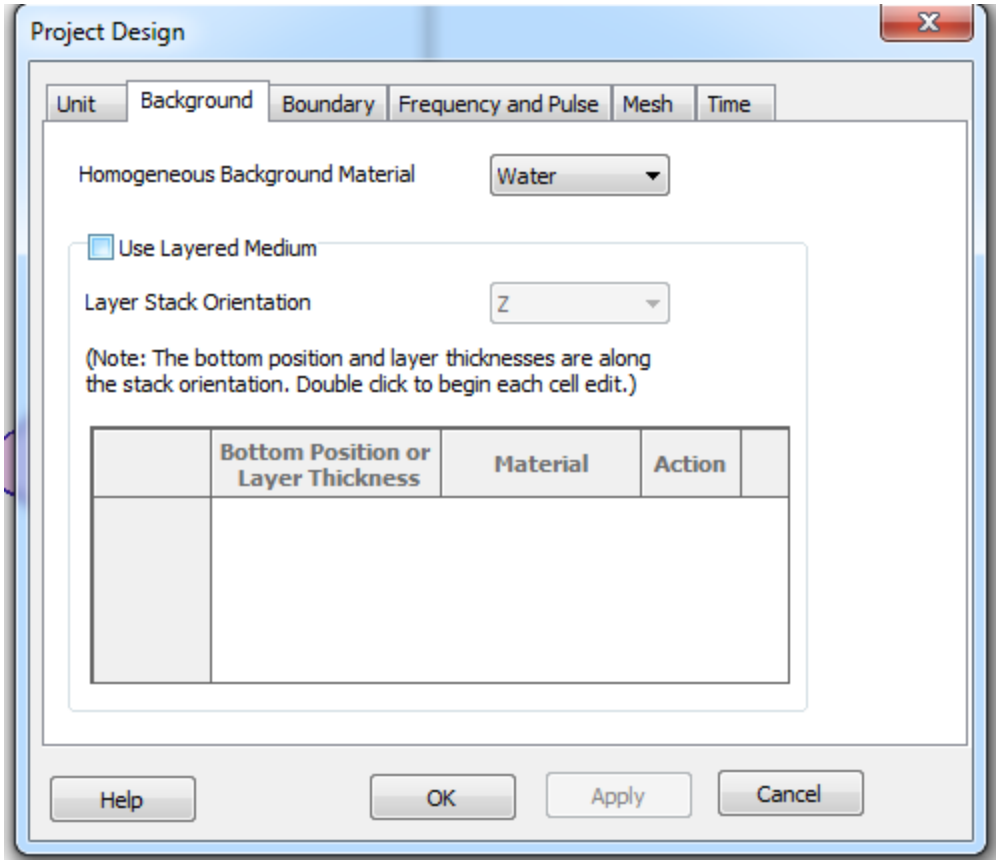
We setup the simulation project with **CM** as unit



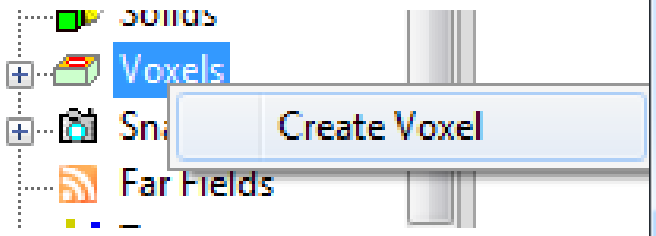
Set project size as following



Set project background as **water**



Then load voxel files



Load
“abc_mass.vxb”,
“abc_vp.vxb”,
“abc_vs.vxb”

Voxel Editor

General
Name: Voxel1
Uint: centimeter

Physical Size
Loaded Volume
Volume Start Position in computation domain (x,y,z): 0, 0, 0
Resolution (dx,dy,dz): 0.075, 0.075, 0.075

Advance
Use the Whole Volume
Use sub-volme
Corner 1 (x,y,z)
Corner 2 (x,y,z)

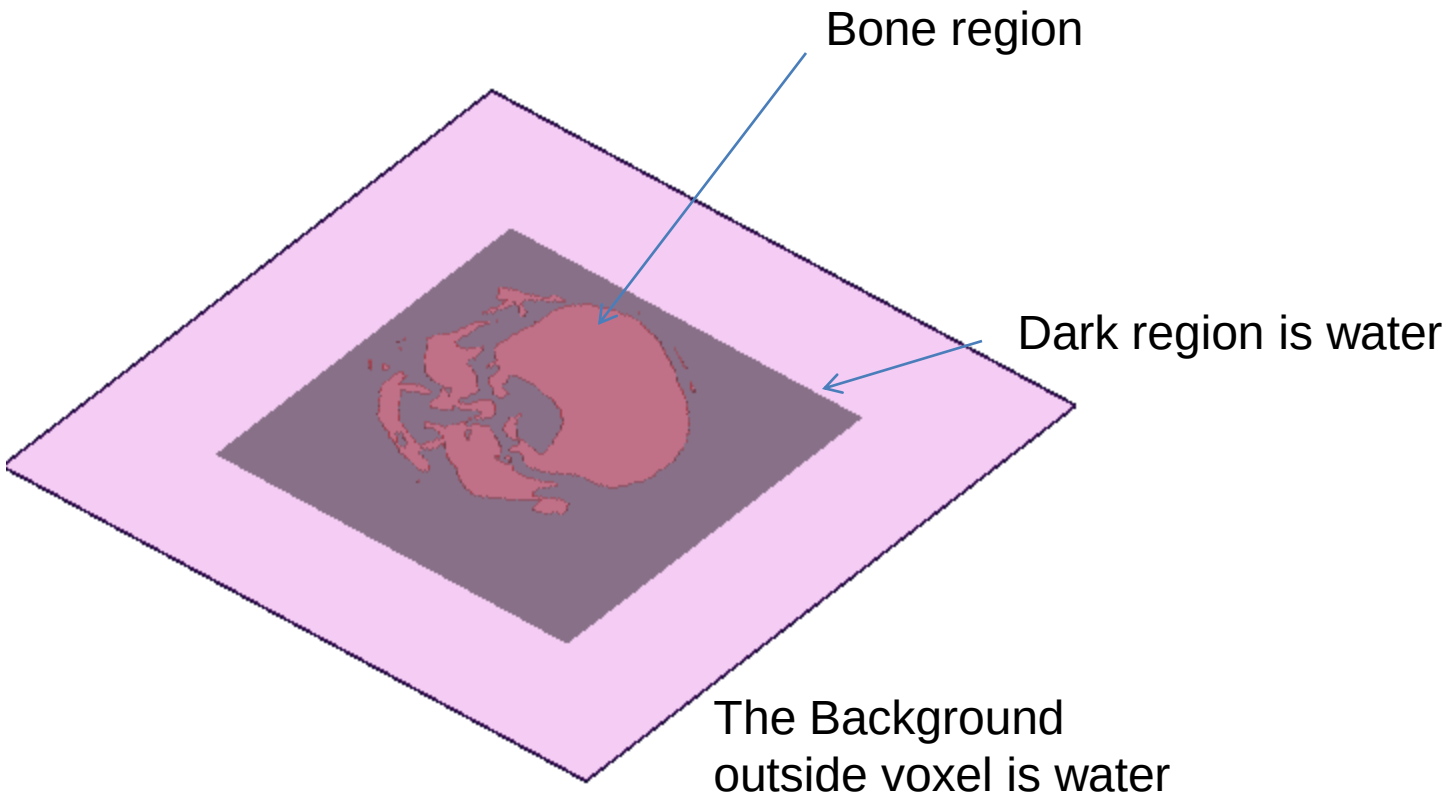
Electrical Parameters | Elastodynamic Parameters | Ela. Weak Aniso. Parameters

Mass (kg/m^3)	Bulk	1000	Load	Mesh Size	200x200x1
Vp (m/s)	Bulk	1500	Load	Mesh Size	200x200x1
Vs (m/s)	Bulk	0	Load	Mesh Size	200x200x1
Qp	Bulk	-1	Load	Mesh Size	
Qs	Bulk	-1	Load	Mesh Size	

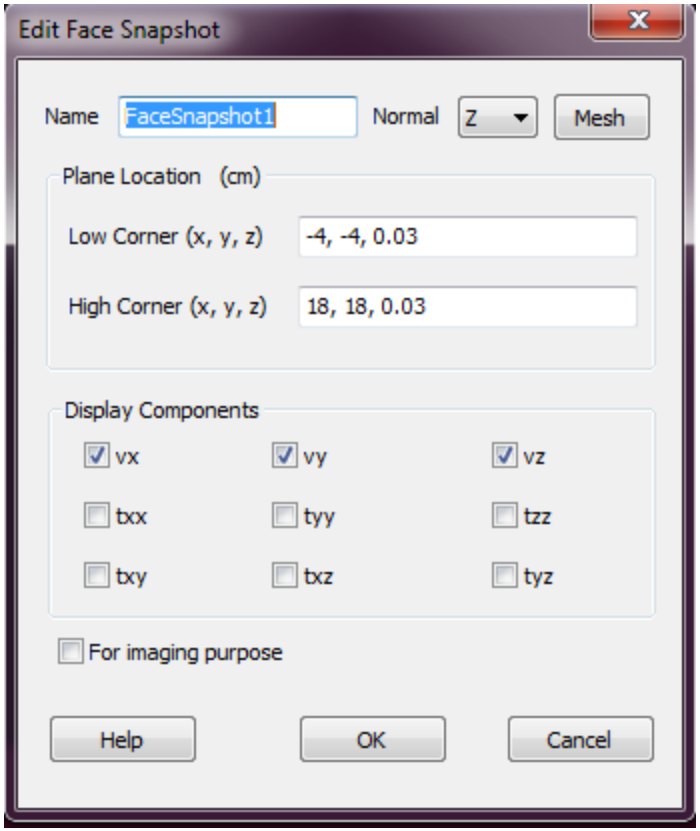
Display
Data Type: Vs
Color Map: Hot
Transparency

Help | OK | Cancel

After “OK”, we get



Then, define a monopole source at (0,0,0). And a 2D snapshot to capture (vx, vy, vz) as following:



Then, we can simulate the project,
and check the snapshot