Near Field Ingestion in Wavenology EM Package

Wave Computation Technologies, Inc.

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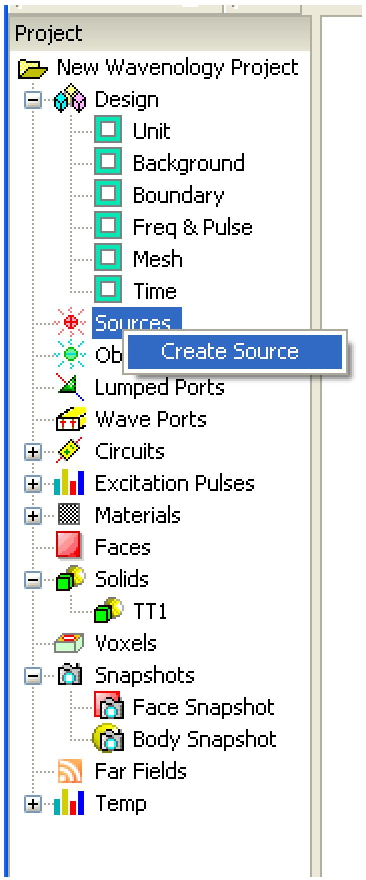
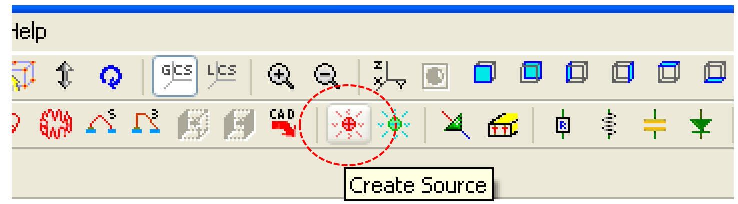
Outline

- Configuration
- NFD File Format
- Examples

CONFIGURATION

Define Near-field Ingestion Source (1)

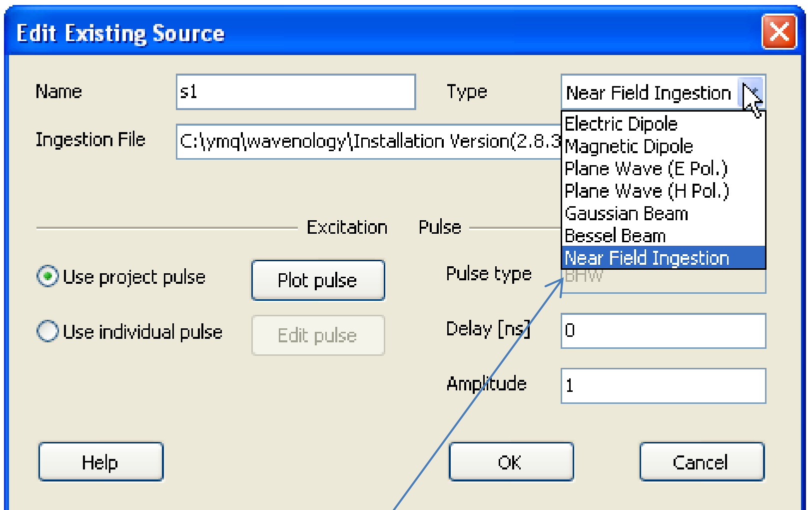


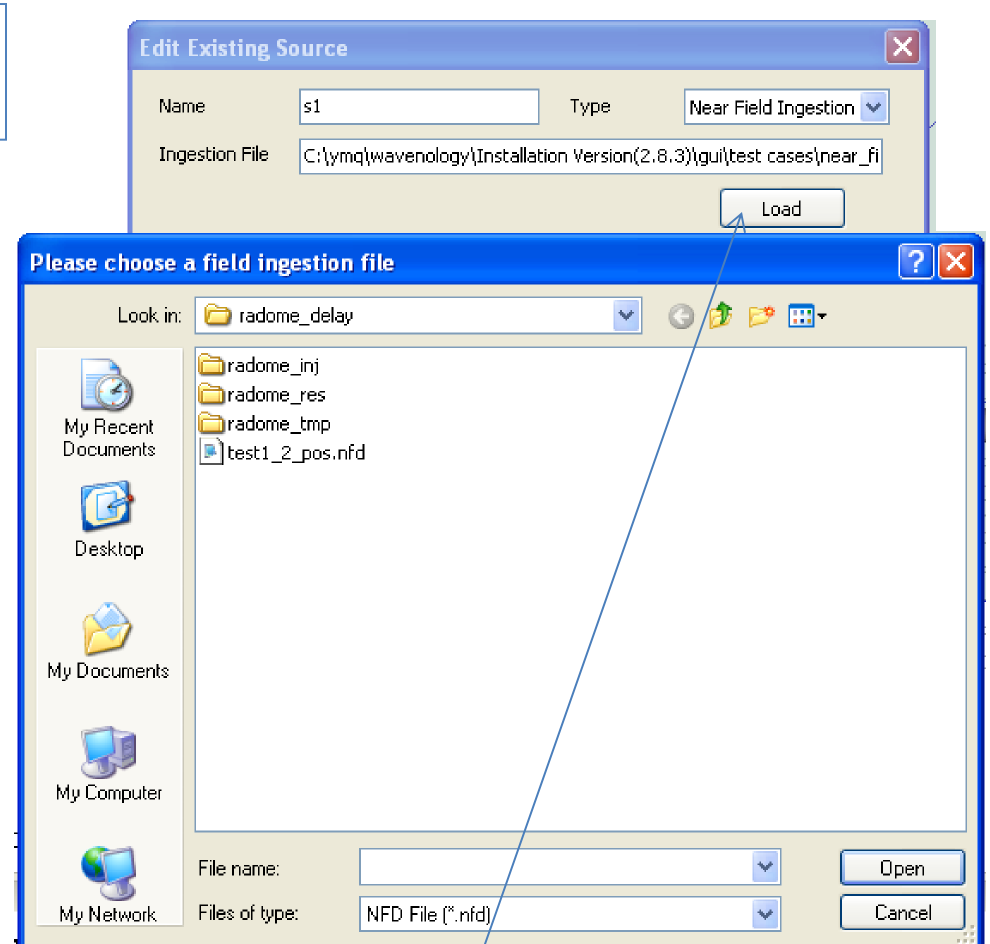


1. Create a new source
   - Right click project-tree "Sources" node and press "Create Source" menu
   - or click toolbar "Create Source" button

Define Near-field Ingestion Source (2)

2. Select source type as "Near field ingestion" and define data file.

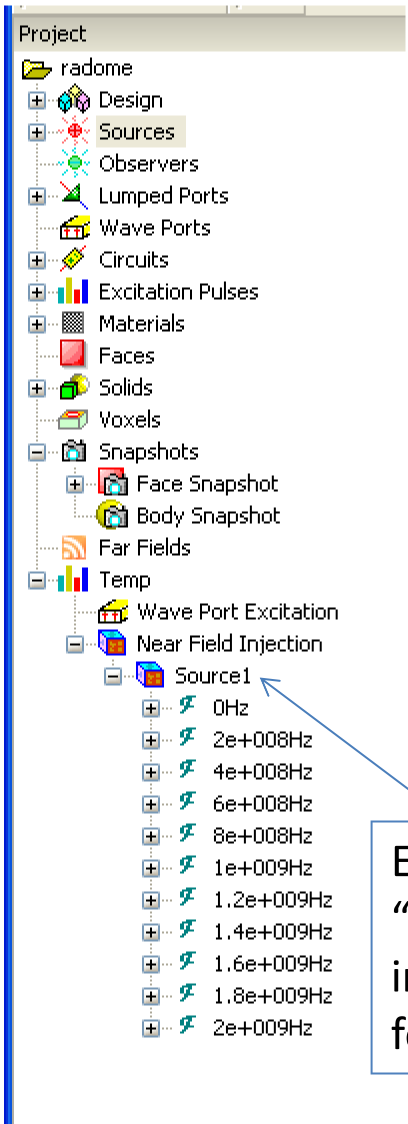




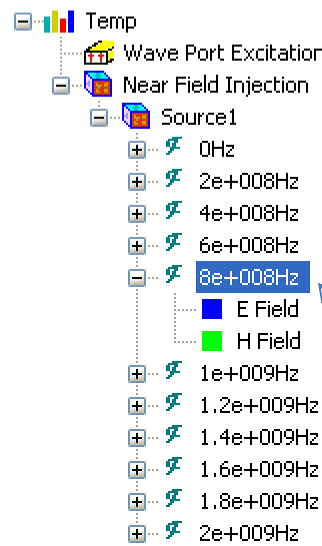
Select source type as "Near field ingestion"

Use load button to load a "NFD" file

Validate the NFD Data (1)

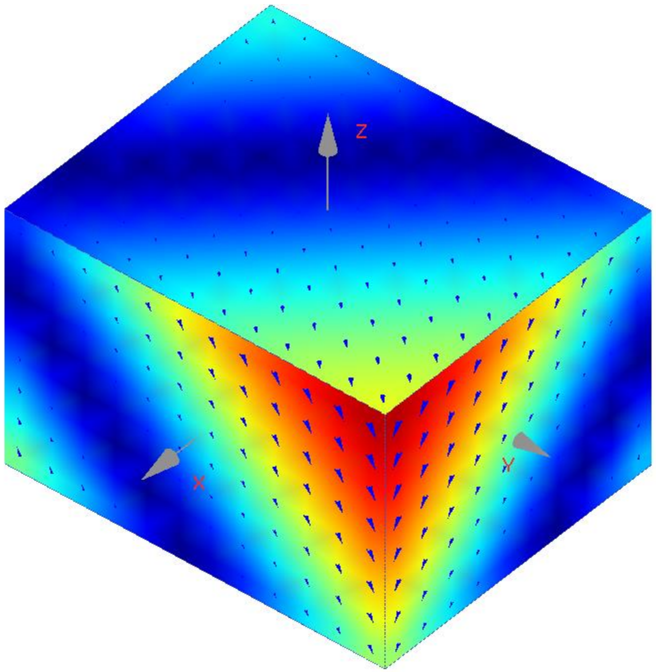


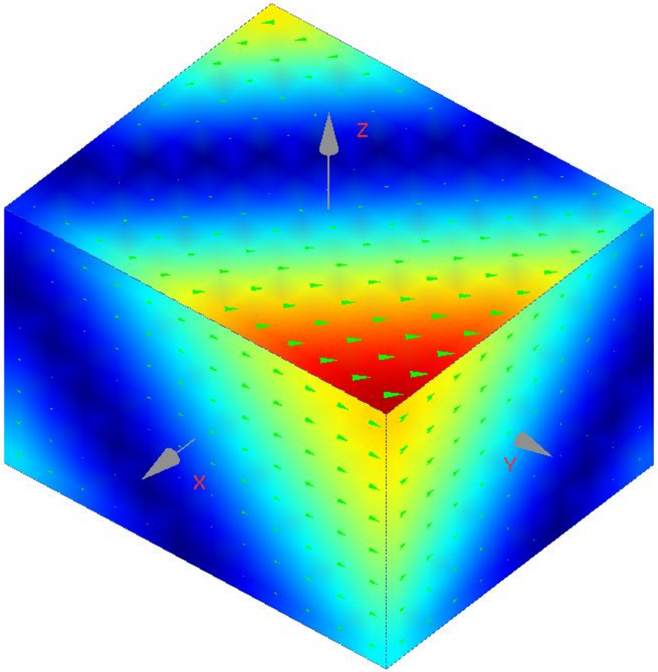
Expand tree node "temp", it lists all NFD input and all freq. data for that input.



Under each freq., user can select E or H to be shown on main canvas.

Validate the NFD Data (2)
the E & H field at 800 MHz





E field distribution on ingestion faces. (we only show the real part of field, the 3D arrow shows the field vector)

H field distribution on ingestion faces

Note: this distribution comes from a plane wave propagates along (54.7356° , 45°) , polarization is (-0.408248, -0.408248, 0.816496)

NFD FILE FORMAT

Supported File Format

- Standard NFD file format, shown as following

```
cell_number 2 2 4      !Number of cells (Nx, Ny, Nz) along x-, y- and z-directions.

cell_size 0.5e-3  0.5e-3  1e-3      !Size of each cell (dx, dy, dz) along x-, y- and z-directions.

box_min -5e-004 -5e-004 -2e-003              !Absolute location of box (Xmin, Ymin, and Zmin).

Data                                          !Each block of data represents one frequency
{
            frequency  1e6
            Xlower
            {
             -4.524009e+003, 3.113550e+003, -2.626592e+003  ...
            }
            Xupper
            {
             -4.524009e+003, 3.113551e+003, -2.626592e+003  ...
            }
            Ylower
            {
             -2.626592e+003, 3.529017e+003, -4.524009e+003  ...
            }
            Yupper
            {
             -2.626592e+003, 3.529018e+003, -4.524008e+003 ...
            }
            Zlower
            {
             -3.340745e+003, 2.408708e+003, -3.340745e+003  ...
            }
            Zupper
            {
             3.340745e+003, -2.408708e+003, 3.340745e+003, -2.408708e+003 ...
            }
}
Data                                          !Each block of data represents one frequency
{
            frequency  2e6
            ...
}
```

Note: in current version, user must follow these rules.
1. Uniform delta frequency, start from 0 Hz.
2. Must provide the values at 0 Hz (can be all 0).
3. The data block must be listed with frequency increasing.
4. All frequency data must be normalized. WCT will modulate the data by user defined NFD pulse.

Review of Data File

Define ingestion place and sampling density

```
cell_number 2 2 4      !Number of cells (Nx, Ny, Nz) along x-, y- and z-directions.

cell_size 0.5e-3  0.5e-3  1e-3     !Size of each cell (dx, dy, dz) along x-, y- and z-directions.

box_min -5e-004 -5e-004 -2e-003               !Absolute location of box (Xmin, Ymin, and Zmin).

Data                                                     !Each block of data represents one frequency
{
                    frequency  1e6
                    Xlower
                    {
                     -4.524009e+003, 3.113550e+003, -2.626592e+003  ...
                    }
                    Xupper
                    {
                     -4.524009e+003, 3.113551e+003, -2.626592e+003 ...
                    }
                    Ylower
                    {
                     -2.626592e+003, 3.529017e+003, -4.524009e+003  ...
                    }
                    Yupper
                    {
                     -2.626592e+003, 3.529018e+003, -4.524008e+003 ...
                    }
                    Zlower
                    {
                     -3.340745e+003, 2.408708e+003, -3.340745e+003  ...
                    }
                    Zupper
                    {
                     3.340745e+003, -2.408708e+003, 3.340745e+003, -2.408708e+003 ...
                    }
}
Data                                                     !Each block of data represents one frequency
{
                    frequency  2e6
                    ...
}
```

Each freq. need one block, including E & H field on 6 surfaces.

Note: in current version, user must follow these rules.

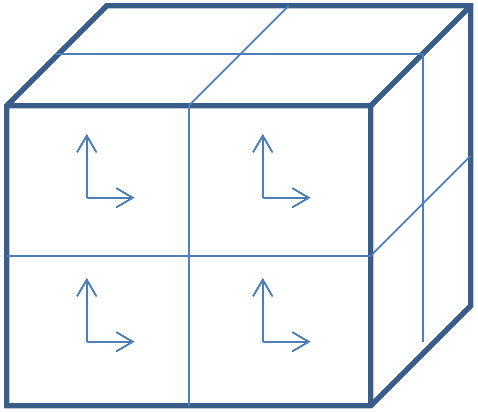
1. Uniform delta frequency, start from 0 Hz.
2. Must provide the values at 0 Hz (can be all 0).
3. The data block must be listed with frequency increasing.
4. All frequency data must be normalized. WCT will modulate the data by user defined NFD pulse.
5. The data in NFD file is tangential E & H field
6. The data in the file is on the surface cell center

File Header

```
! NFD test case1, aperture farfield
cell_number    nx    ny    nz
cell_size      Δx    Δy    Δz
box_min        x     y     z
```

1. The 1st line is comment, start from "! NFD"
2. 2nd line is the uniform near field ingestion mesh size along x, y & z axis
3. 3rd line is the cell size for the uniform mesh
4. The start position of ingestion mesh

Note: the unit of above item is project unit.



The data in the file is on the surface cell center

Data Block

```
data
{
    frequency 0.000000e+000
    Xlower
    {
        -0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00, - 0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00
        ....
    }
    Xupper
    {
        -0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00, - 0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00
        ....
    }
    Ylower
    {
        -0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00, - 0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00
        ....
    }
    Yupper
    {
        -0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00, - 0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00
        ....
    }
    Zlower
    {
        -0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00, - 0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00
        ....
    }
    Zupper
    {
        -0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00, - 0.00e+00, + 0.00e+00, + 0.00e+00, + 0.00e+00
        ....
    }
}
```

Each data block include the tangential E & H field on the 6 surfaces for one freq.

The format is as the left figure.

Field on Ingestion Surface

X_{min}/X_{max} Plane

```
Xlower
{
   -0.00e+00, + 0.00e+00,| + 0.00e+00, + 0.00e+00,| - 0.00e+00, + 0.00e+00,| + 0.00e+00, + 0.00e+00
   ....  Ey(Re,Im)          Ez(Re,Im)                Hy(Re,Im)                Hz(Re,Im)
}
Xupper
{
   -0.00e+00, + 0.00e+00,| + 0.00e+00, + 0.00e+00,| - 0.00e+00, + 0.00e+00,| + 0.00e+00, + 0.00e+00
   ....  Ey(Re,Im)          Ez(Re,Im)                Hy(Re,Im)                Hz(Re,Im)
}
```

Because we only use the tangential component of field (in freq. domain), there are

- 4 field for each position
  - Each field include real part and the imaginary part.

Field on Ingestion Surface

Y_{min}/Y_{max} Plane

Ylower

{

-0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00,	- 0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00
E_z(Re,Im)	E_x(Re,Im)	H_z(Re,Im)	H_x(Re,Im)

....

}

Xupper

{

-0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00,	- 0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00
E_z(Re,Im)	E_x(Re,Im)	H_z(Re,Im)	H_x(Re,Im)

....

}

Field on Ingestion Surface

Z_{min}/Z_{max} Plane

Zlower
{

-0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00,	- 0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00
E_x(Re,Im)	E_y(Re,Im)	H_x(Re,Im)	H_y(Re,Im)

....
}

Zupper
{

-0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00,	- 0.00e+00, + 0.00e+00,	+ 0.00e+00, + 0.00e+00
E_x(Re,Im)	E_y(Re,Im)	H_x(Re,Im)	H_y(Re,Im)

....
}

Example for Generating NFD File Plane Wave Propagate Along Y

We provide a matlab code to generate the plane wave incident along Y axis. The matlab code is "WavenologyEM_Tutorial_NearFieldIngestion_planewave_yinc.m"

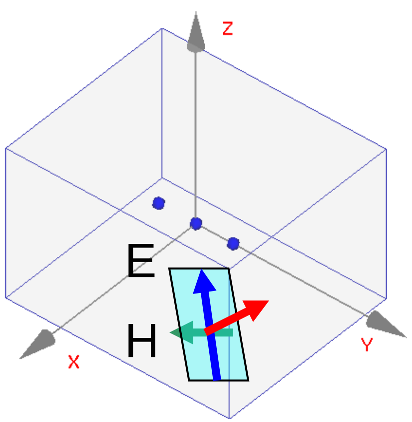
EXAMPLES

Example 1: A Far-Field Plane Wave Ingestion Source

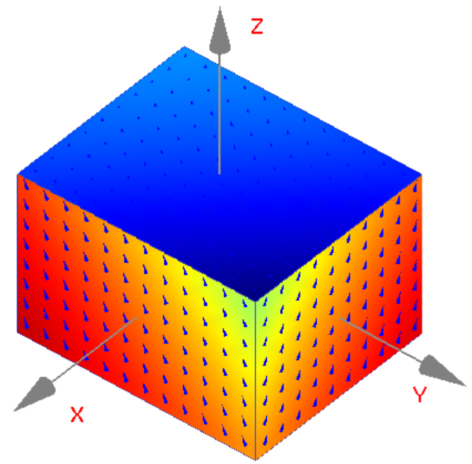
- In this case, we compare two situations

1. A internal regular plane wave propagates along (54.7356, 45) degree, polarization is (-0.408248, -0.408248, 0.816496), homogenous background – air

2. Using analytical method to build normalized NFD data on 6 faces for above plane wave. In this case, we produce the data at [0, 0.2, 0.4, …, 1.6, 2] GHz.

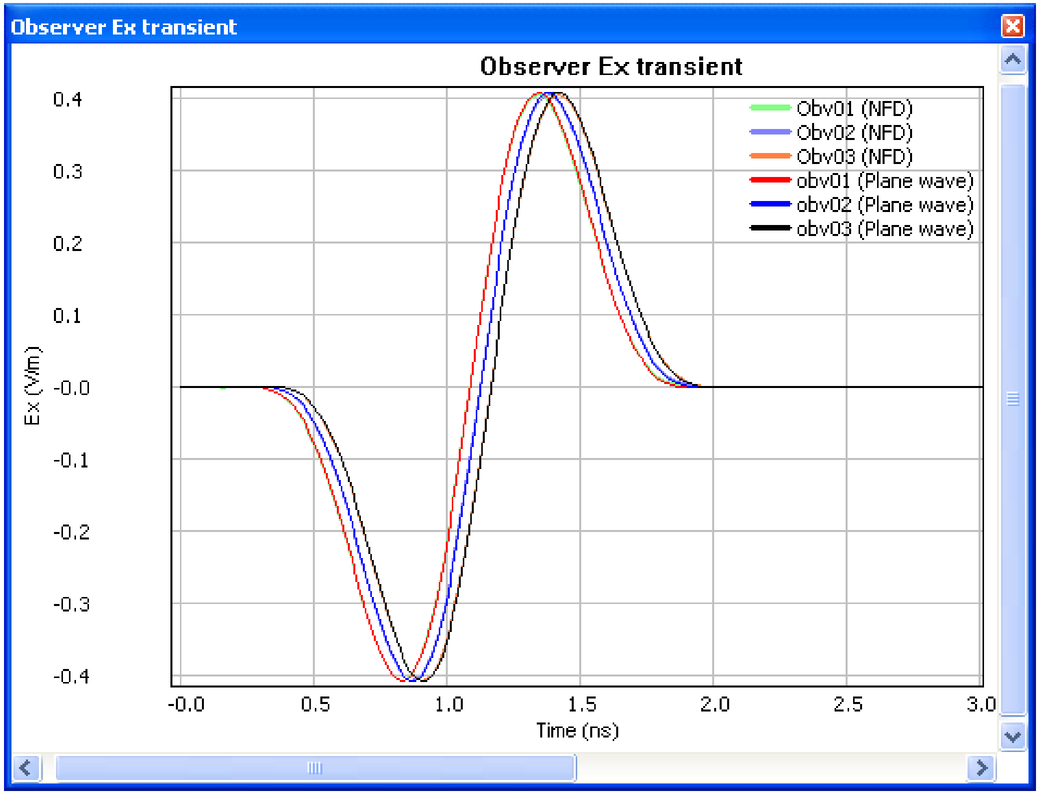


Regular plane wave incident:
the 3 blue dots are observers



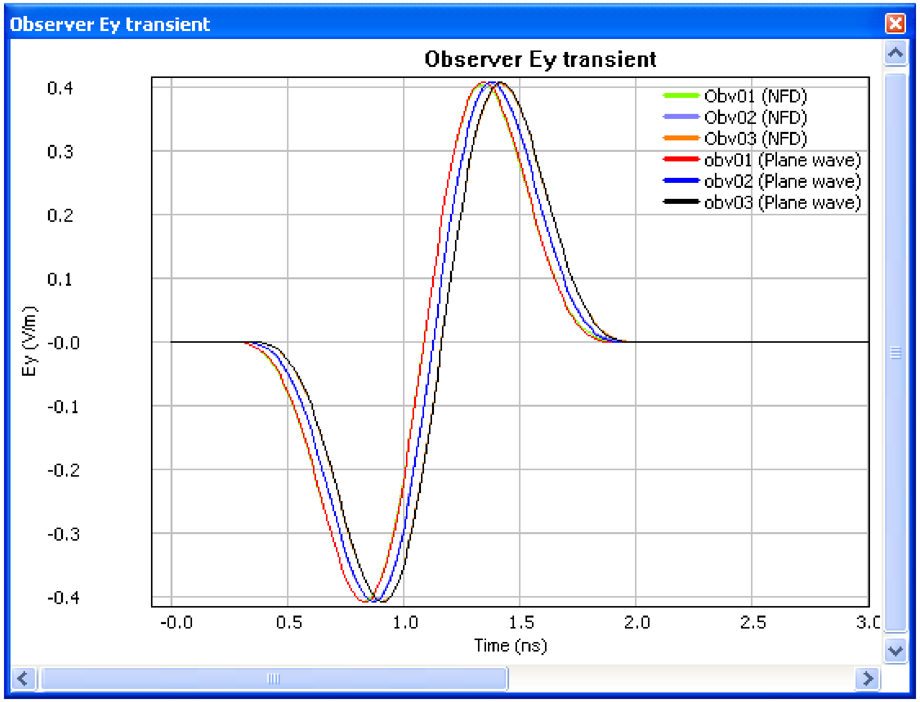
NFD ingestion incident:
E field distribution on
ingestion faces at 200 MHz

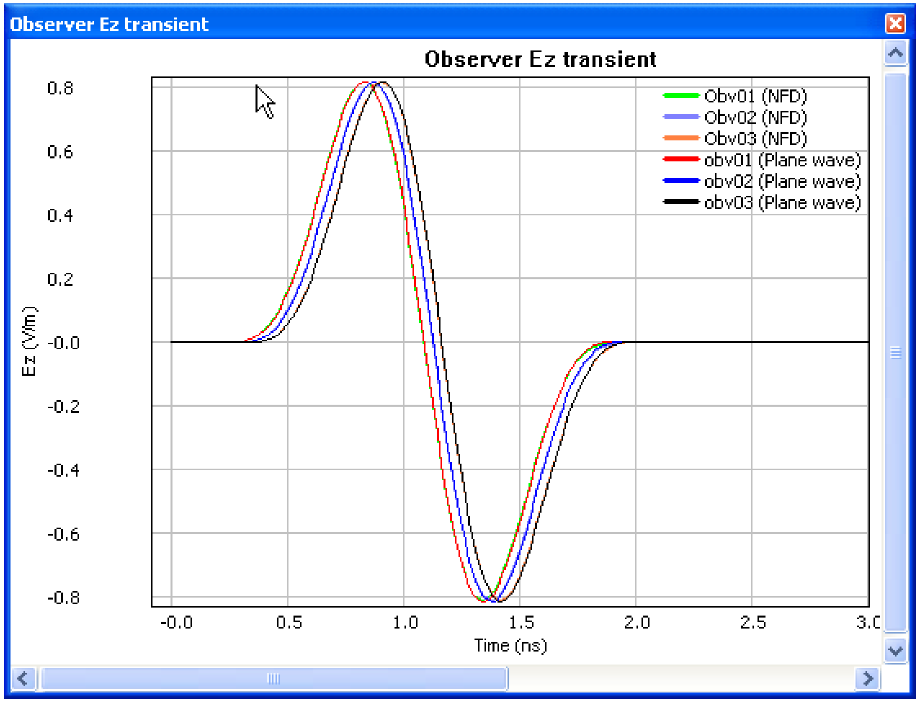
Result Comparison
Observer Ex Transient Results



As can be seen, the two cases' Ex , Ey and Ez on the same observer are agree very well, this means the NFD ingestion is the same as regular plane wave incident.

Result Comparison
Observer Ey & Ez Transient Results

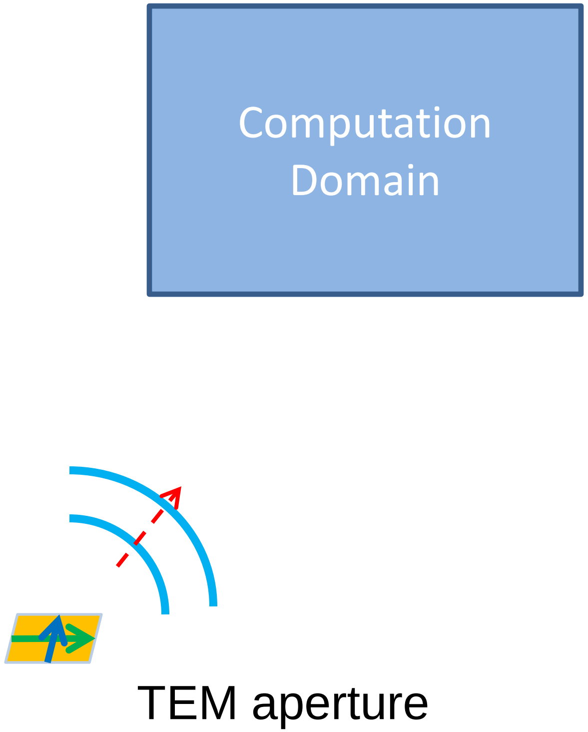




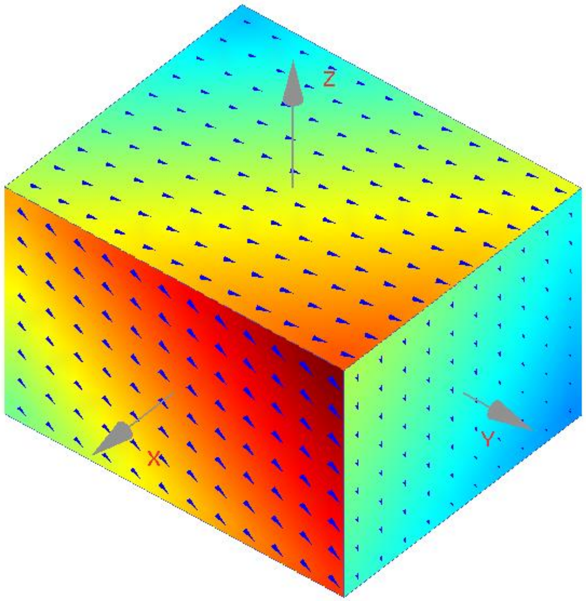
Example 2: A Near-Field Ingestion Current Source

In this case, we use a near-field ingestion current source to represent a TEM aperture far away from the computation domain.

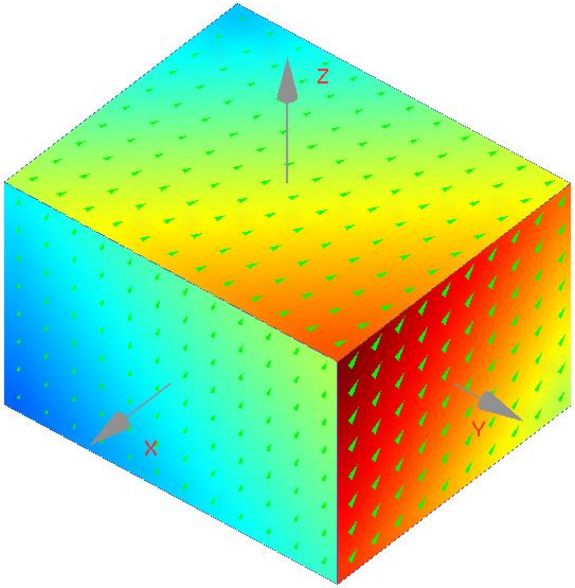
- The TEM aperture is at (-10, -20, -20) m.
- The Near-Field ingestion is obtained analytically from the far field estimation for above aperture.
- The computation domain is (-0.05, -0.06, -0.04)~(0.05, 0.06, 0.04) m, there are 2 observers at (-35, -35, -35) and (35, 35, 35) mm.



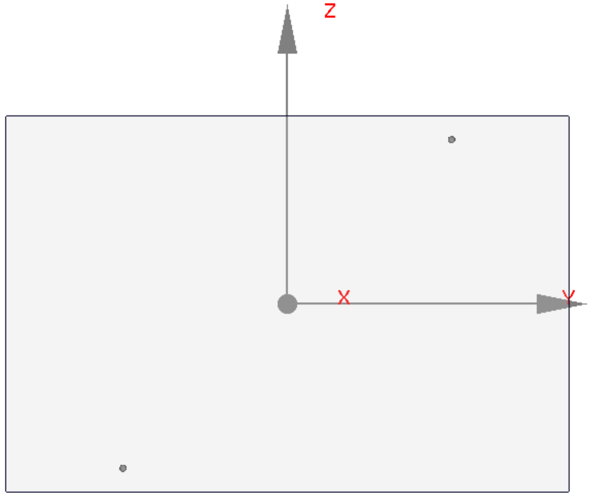
(case "example_2.8/ NFD_ingestion/3.wnt")



E field distribution on ingestion faces (200 MHz)

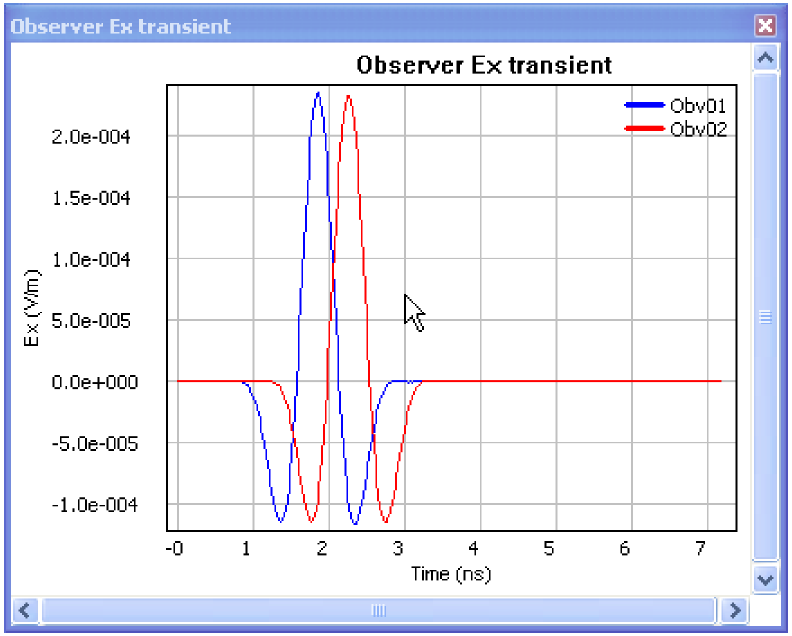


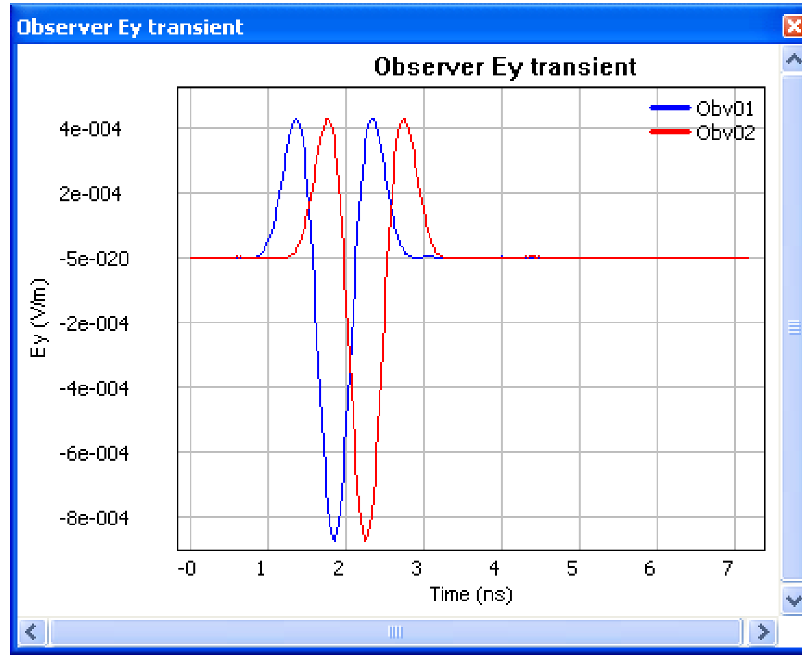
H field distribution on ingestion faces (200 MHz)

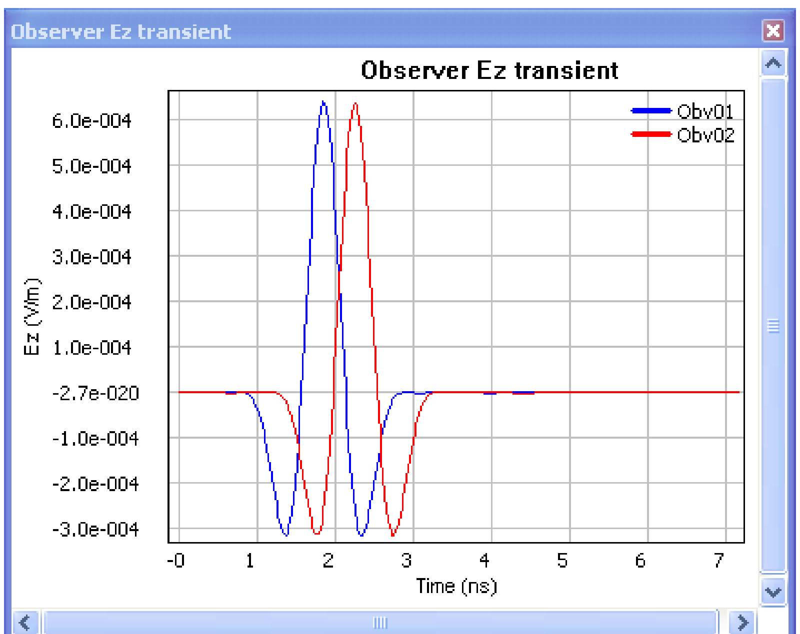


2 observers are at (-35,-35,-35), (35,35,35) mm

Observer Ex, Ey & Ez Trans. Results





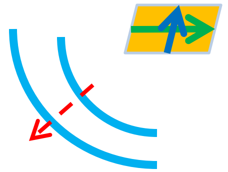


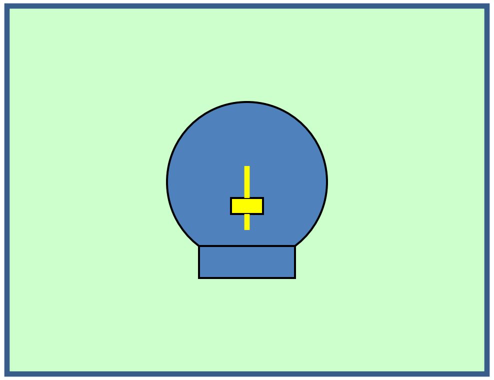
The NFD comes from a TEM aperture at (-10,-20,-20) m. For the observers in computation domain, the ingestion is similar to a plane wave. The result meet our expectation.

Example 3: A Near-Field Ingestion Current Source for Radome Structure

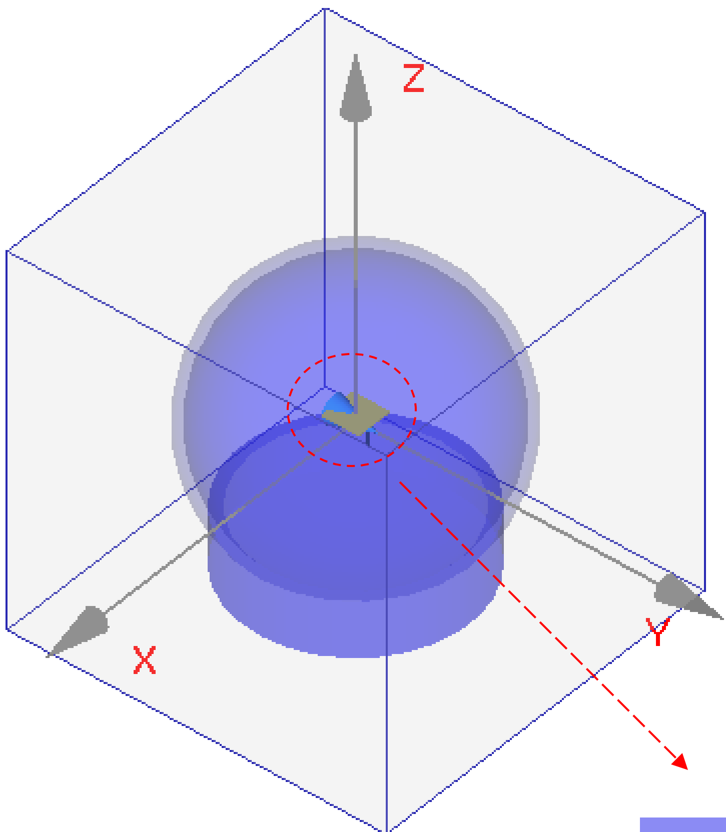
In this case, we use a near-field ingestion current source to represent a TEM aperture far away from the computation domain.
• The TEM aperture is at (20, 20, 20) m.
• The Near-Field ingestion is obtained analytically from the far field estimation for above aperture.
• The computation domain is (-0.5, -0.5, -0.5)~(0.5, 0.5, 0.5) m, there are one monopole antenna placed in a dielectric shell to detect the signal propagating in the shell.

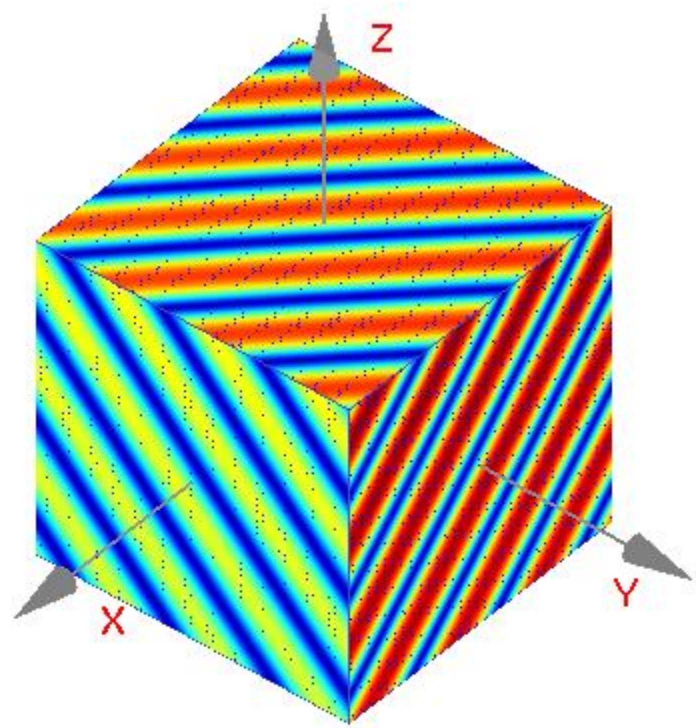
TEM aperture





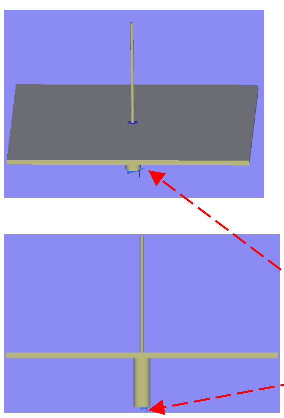
Receiving Antenna
in dielectric shell





E field distribution on ingestion faces (800 MHz)

Radome Structure

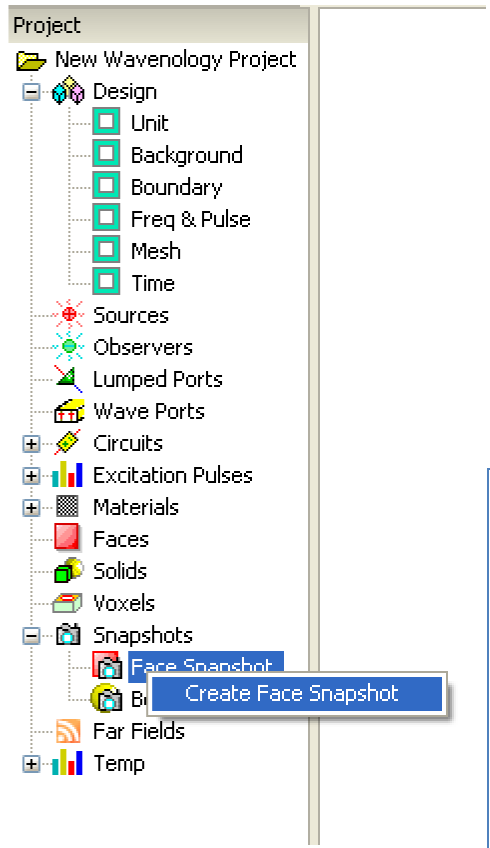


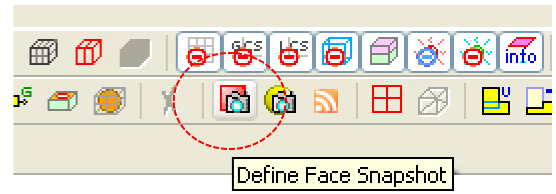
Lumped port used to measured the signal received by antenna

Monopole antenna

Wave Propagation Monitored by 2D Snapshot (1)

In this case, we define a 2D face snapshot to monitor how the EM wave propagates in the computation domain.



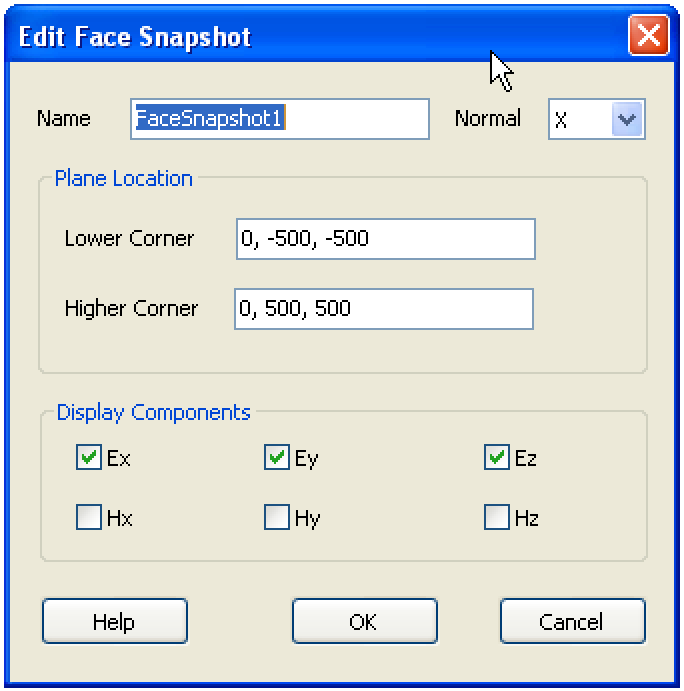


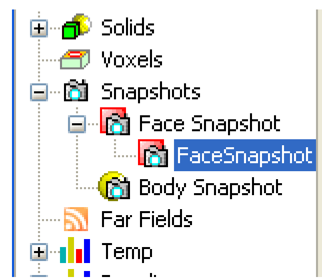
Create a 2D face snapshot

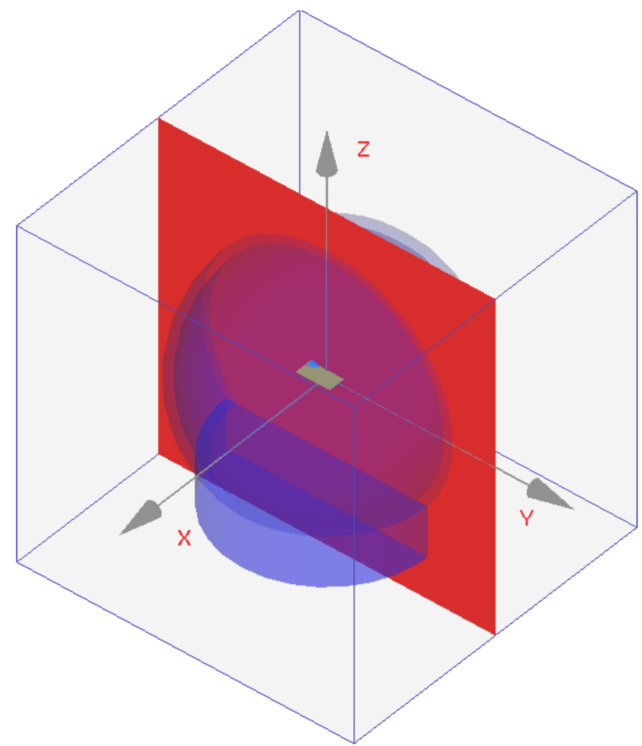
- Right click project-tree “Snapshot->Face Snapshot” node and press “Create Face Snapshots” menu
- or click toolbar “Define Face Snapshots” button

Wave Propagation Monitored by 2D Snapshot (2)

After creating a snapshot, user can click the snapshot's name to highlight it in the main canvas to verify the snapshot position.

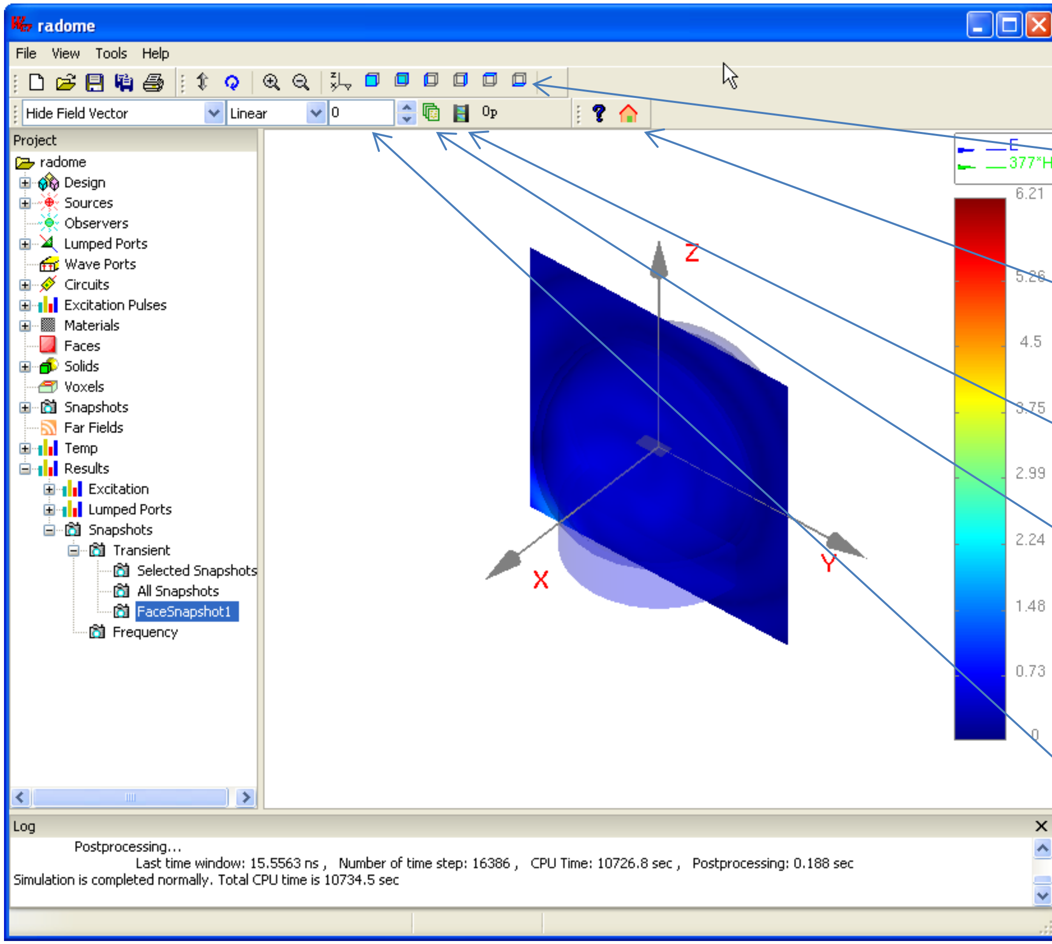






Because it is free 2D snapshot in computation domain, user need to define the snapshot position and the fields to be recorded.

Display Recorded Data on Snapshot



Change View Angle

Exit to normal view mode

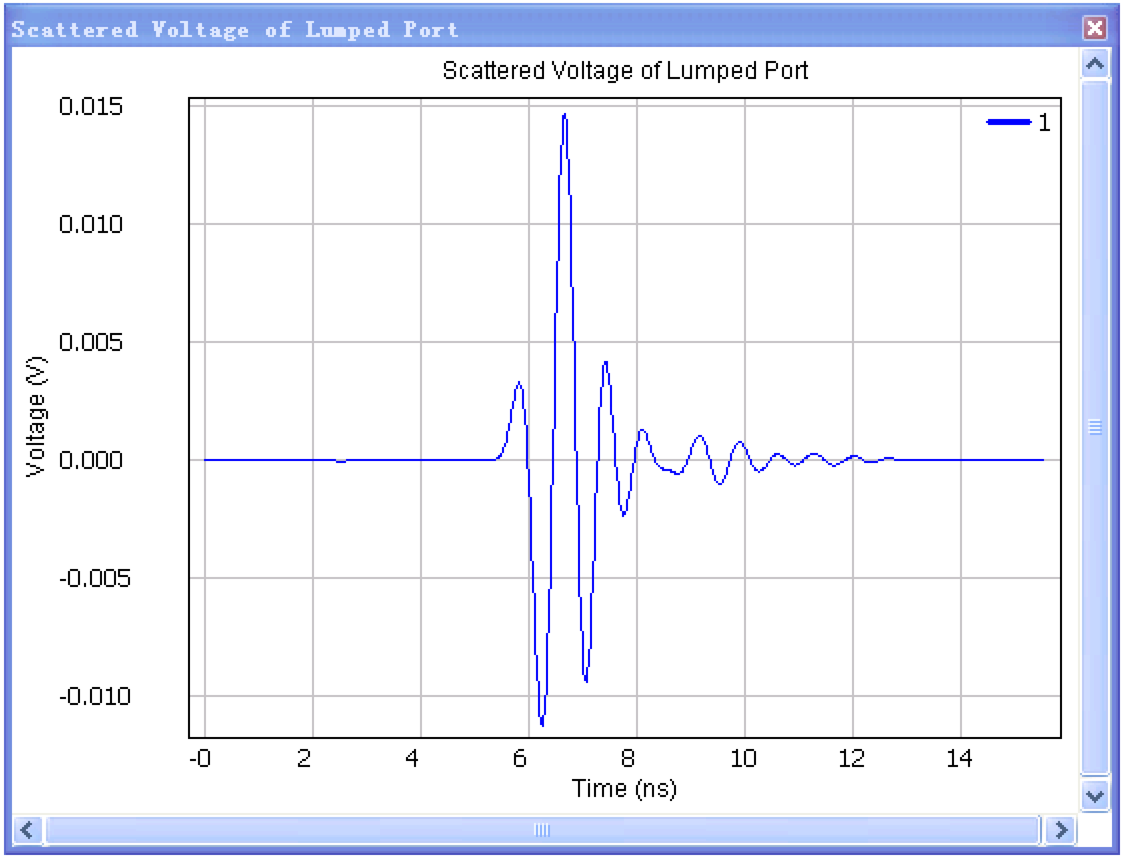
Make movie

Auto display

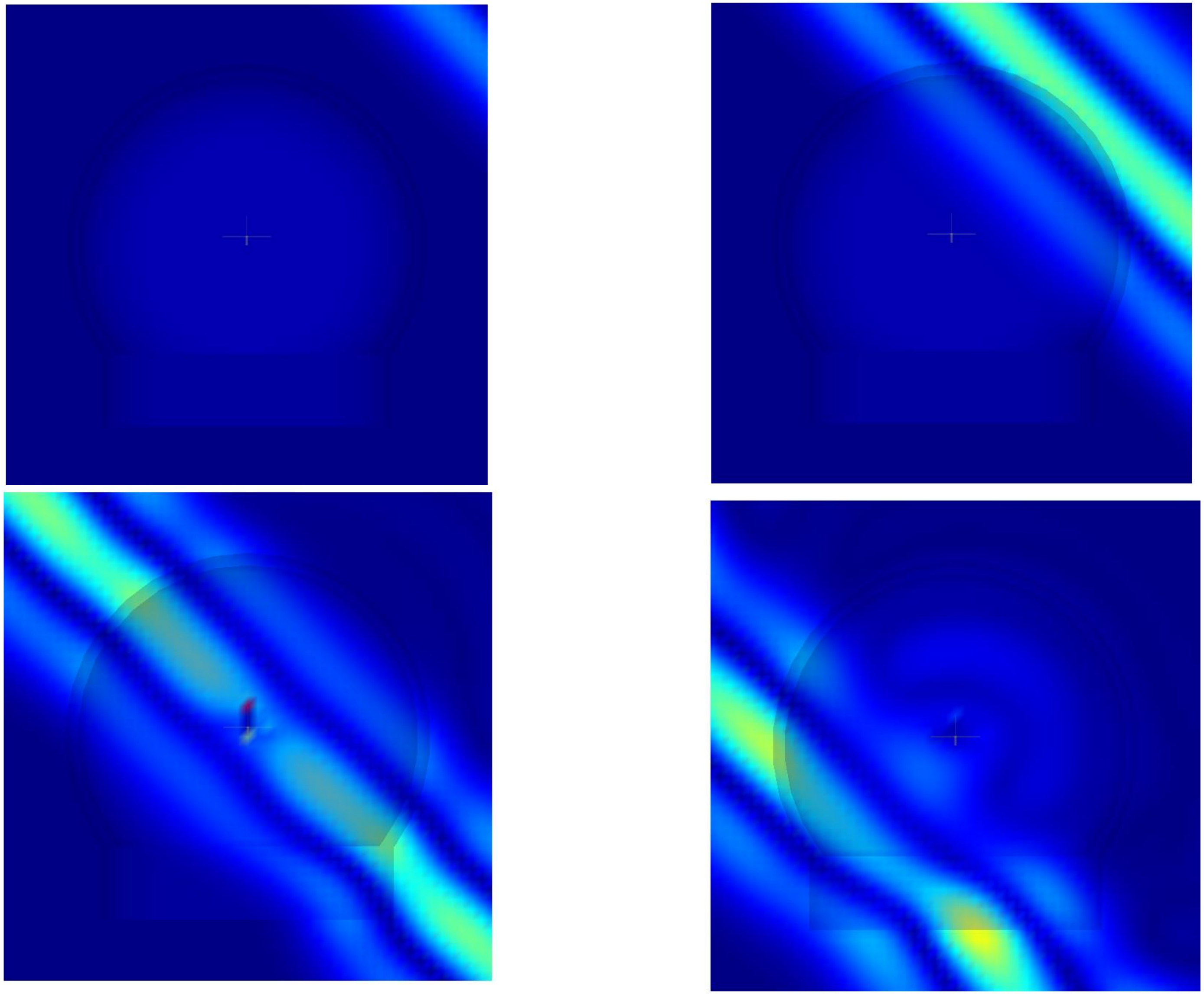
Current displayed frame index. User can change this value to show different frames.

Expand project-tree “Results->Snapshots->Transient” node and click any snapshot to show it. The main canvas will be switched to “Snapshot Displaying Mode”.

Scattered Transient Voltage on Lumped Port



Wave Propagation on X=0 Plane
Linear Scale



Wave Propagation on X=0 Plane
Log Scale