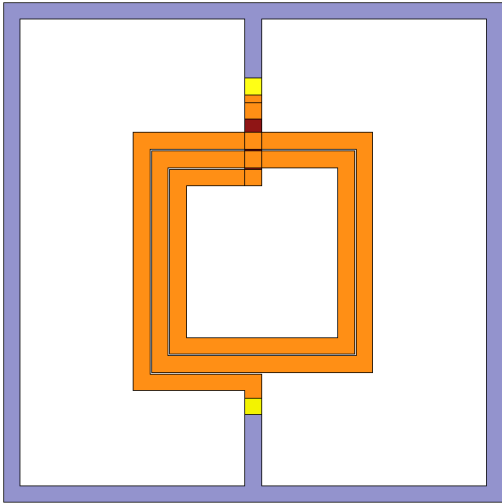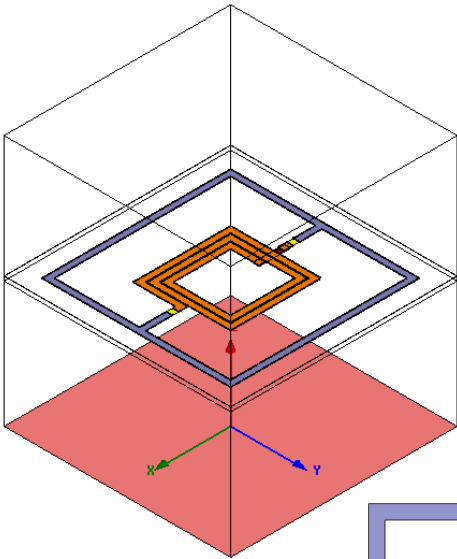# An Introduction to HFSS

**Workshop 4.1 – HFSS
Example: Silicon Spiral Inductor**

Example – Silicon Spiral Inductor

- **The Silicon Spiral Inductor**
    - This example is intended to show you how to create, simulate, and analyze a 2.5 turn spiral inductor using the Ansoft HFSS Design Environment.

Nominal Design:

> **Spiral:** 2.5T, W=15um, S=1.5um, Rad=60um
>
> M6, 2um, σ= 2.8e7 S/m
>
> **Underpass:** M5, 0.5um, σ= 2.8e7 S/m
>
> **Stackup:**
>
> > **Passivation:** 0.7um
> >
> > $\varepsilon r = 7.9$
> >
> > **Oxide:** 9.8um
> >
> > $\varepsilon r = 4.0$
> >
> > **Substrate:** 300um
> >
> > $\varepsilon r = 11.9$, σ= 10 S/m

Example – Silicon Spiral Inductor

- **Ansoft HFSS Design Environment**
  - The following features of the Ansoft HFSS Design Environment are used to create this passive device model
    - 3D Solid Modeling
      - Primitives: **Box, Rectangles, Cylinders**
      - Boolean Operations: **Subtract, Unite, Duplicate**
    - Boundary
      - Boundary Conditions: **Perfect H/Natural**
    - Excitations
      - Ports: **Lumped Gap Source Port**
    - Analysis
      - Sweep**: Fast Frequency**
    - Results
      - **Cartesian plotting**
    - Fields
      - **Fast Frequency Sweep/Field Plots**

Example – Silicon Spiral Inductor

- **Getting Started**

- **Launching Ansoft HFSS**
    - To access Ansoft HFSS, click the Microsoft **Start** button, select **Programs**, and select the **Ansoft, HFSS 12** program group. Click **HFSS 12**.

- **Setting Tool Options**
    - **To set the tool options:**
        - **Note:** In order to follow the steps outlined in this example, verify that the following tool options are set **:**
        - Select the menu item *Tools > Options > HFSS Options*
        - HFSS Options Window:
            - Click the **General** tab
                - Use Wizards for data entry when creating new boundaries**: ☑ Checked**
                - Duplicate boundaries/mesh operations with geometry**: ☑ Checked**
                - Auto-assign terminals on ports:**: ☑ Checked**
            - Click the **OK** button
        - Select the menu item *Tools > Options > Modeler Options*.
        - Modeler Options Window:
            - Click the **Operation** tab
                - Automatically cover closed polylines**: ☑ Checked**
            - Click the **Drawing** tab
                - Operation Data Entry Mode: **Point**
                - Show Measure Dialog : ☐ **Unchecked**
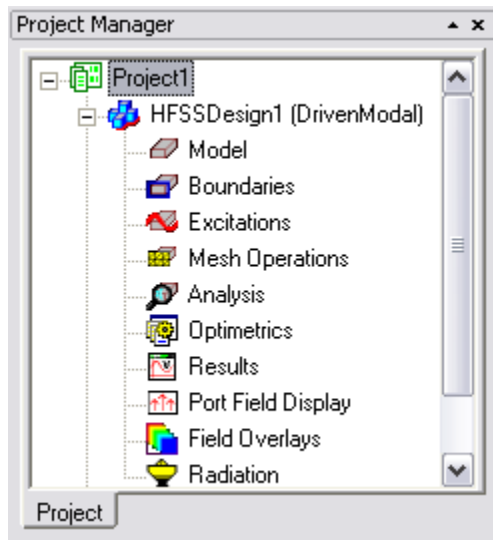   - Edit property of new primitives**: ☑ Checked**
            - Click the **OK** button

Example –Silicon Spiral Inductor

- **Opening a New Project**
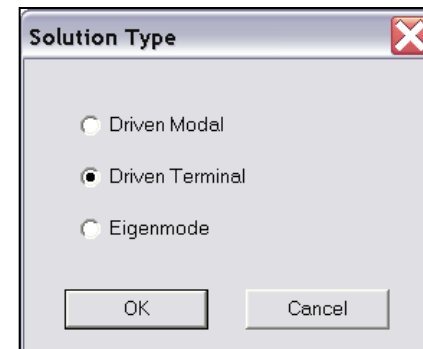
    – **To open a new project:**
        - In an Ansoft HFSS window, click the ▯ On the Standard toolbar, or select the menu item *File > New*.
        - From the *Project* menu, select *Insert HFSS Design.*

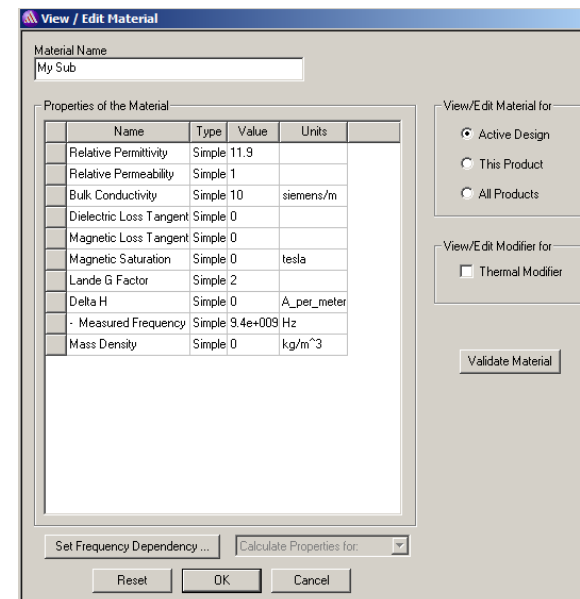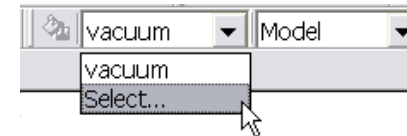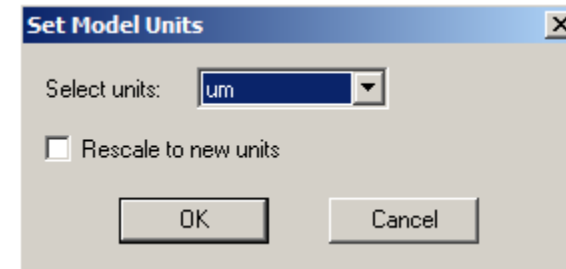- **Set Solution Type**
    – **To set the solution type:**
        - Select the menu item *HFSS > Solution Type*
        - Solution Type Window:
            – Choose **Driven Terminal**
            – Click the **OK** button

Example – Silicon Spiral Inductor

- **Creating the 3D Model**

- **Set Model Units**
  - **To set the units:**
    - Select the menu item ***3D Modeler > Units***
    - Set Model Units:
      - Select Units: **um**
      - Click the **OK** button

- **Set Default Material**
  - **To set the default material:**
    - Using the 3D Modeler Materials toolbar, choose **Select**
    - Select Definition Window:
      - Click the **Add Material** button
      - View/Edit Material Window:
        - For the **Material Name** type: **My_Sub**
        - For the **Value** of **Relative Permittivity** type: **11.9**
        - For the **Value** of **Bulk Conductivity** type: **10**
        - Click the **OK** button
      - Click the **OK** button

Set Model Units

Select units: um

☐ Rescale to new units

OK   Cancel

vacuum   Model
vacuum
Select...

View / Edit Material

Material Name
My Sub

Properties of the Material

	Name	Type	Value	Units
	Relative Permittivity	Simple	11.9	
	Relative Permeability	Simple	1	
	Bulk Conductivity	Simple	10	siemens/m
	Dielectric Loss Tangent	Simple	0	
	Magnetic Loss Tangent	Simple	0	
	Magnetic Saturation	Simple	0	tesla
	Lande G Factor	Simple	2	
	Delta H	Simple	0	A_per_meter
	- Measured Frequency	Simple	9.4e+009	Hz
	Mass Density	Simple	0	kg/m^3

View/Edit Material for
◉ Active Design
○ This Product
○ All Products

View/Edit Modifier for
☐ Thermal Modifier

Validate Material

Set Frequency Dependency ...   Calculate Properties for:
Reset   OK   Cancel
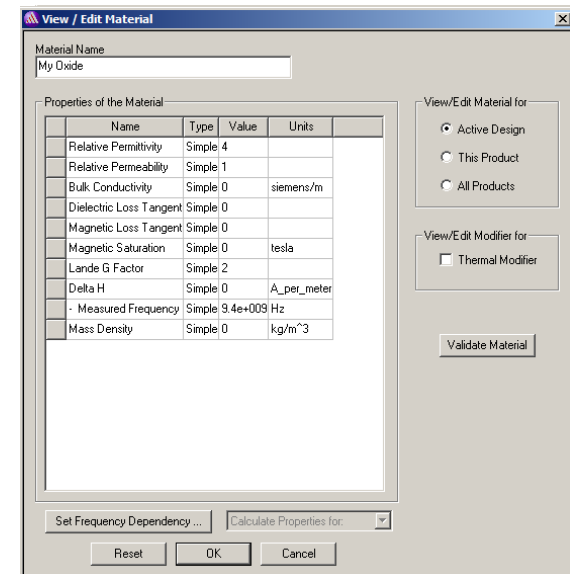
- **Create Substrate**
  - **To create the substrate:**
    - Select the menu item *Draw > Box*
    - *U*sing the coordinate entry fields, enter the box position
      - X: **-270.0**, Y: **-270.0**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **540.0**, dY: **540.0**, dZ: **300.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Sub**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View*.
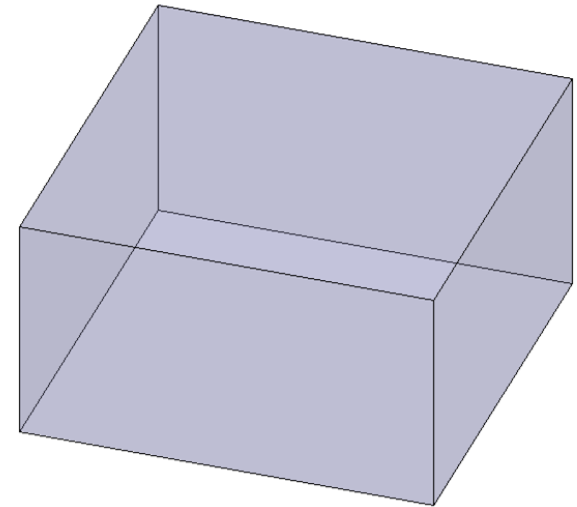
- **Set Default Material**
  - **To set the default material:**
    - Using the 3D Modeler Materials toolbar, choose **Select**
    - Select Definition Window:
      - Click the **Add Material** button
      - View/Edit Material Window:
        - For the **Material Name** type: **My_Oxide**
        - For the **Value** of **Relative Permittivity** type: **4.0**
        - Click the **OK** button
      - Click the **OK** button

Example – Silicon Spiral Inductor

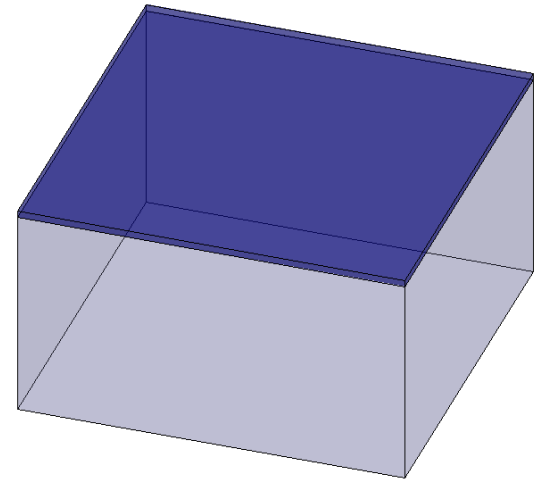- **Create Oxide**
  - **To create substrate:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-270.0**, Y: **-270.0**, Z: **300.0**, Press the **Enter** key\
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **540.0**, dY: **540.0**, dZ: **9.8**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Oxide**
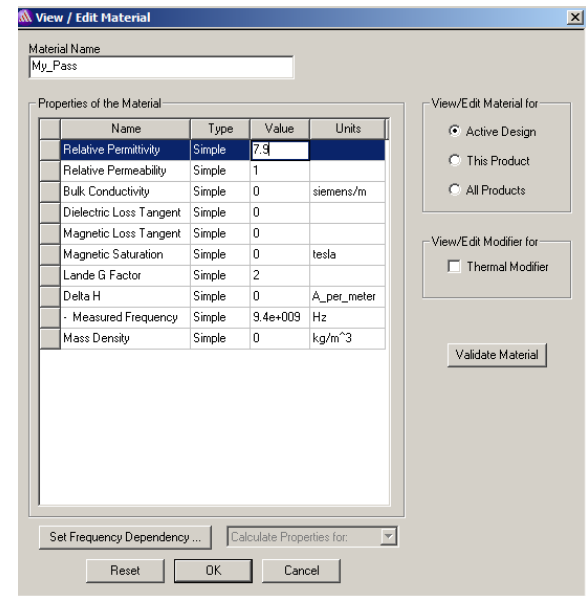   - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View*
      or press the **CTRL+D** key

- **Set Default Material**
  - **To set the default material:**
    - Using the 3D Modeler Materials toolbar, choose **Select**
    - Select Definition Window:
      - Click the **Add Material** button
      - View/Edit Material Window:
        - For the **Material Name** type: **My_Pass**
        - For the **Value** of **Relative Permittivity** type: **7.9**
        - Click the **OK** button
      - Click the **OK** button

Example – Silicon Spiral Inductor

- **Create Passivation**
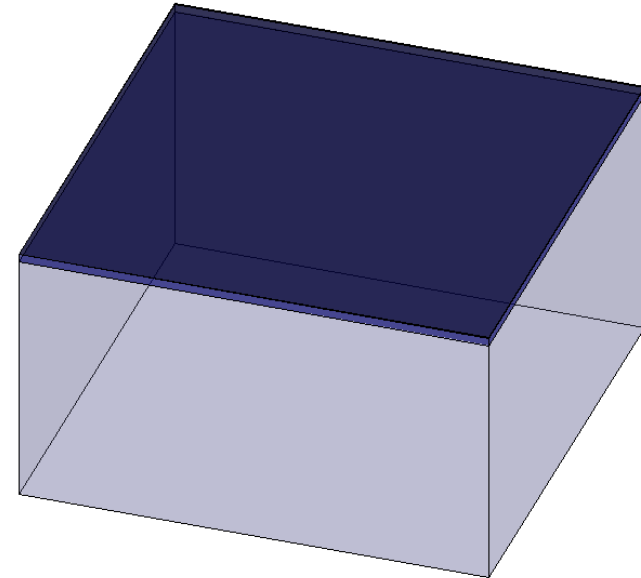 - **To create substrate:**
    - Select the menu item ***Draw > Box***
    - Using the coordinate entry fields, enter the box position
      - X: **-270.0**, Y: **-270.0**, Z: **309.8**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **540.0**, dY: **540.0**, dZ: **0.7**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Pass**
    - Click the **OK** button
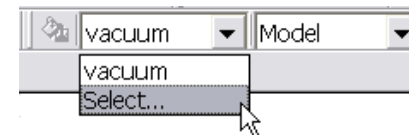 - **To fit the view:**
    - Select the menu item ***View > Fit All > Active View***
    or press the **CTRL+D** key

- **Set Default Material**
 - **To set the default material:**
    1. Using the 3D Modeler Materials toolbar, choose **vacuum**
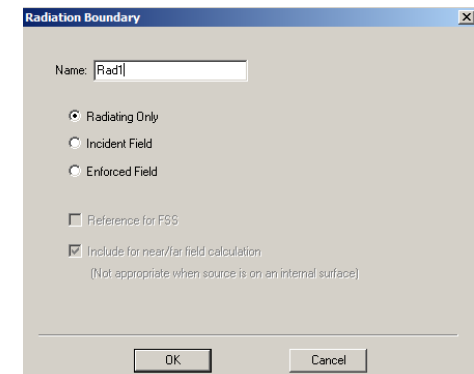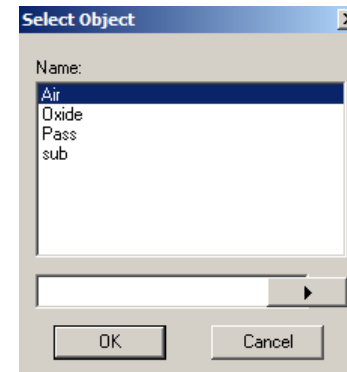
Example – Silicon Spiral Inductor

- **Create Air**
  - **To create air box:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-270.0**, Y: **-270.0**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **540.0**, dY: **540.0**, dZ: **600.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Air**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View*
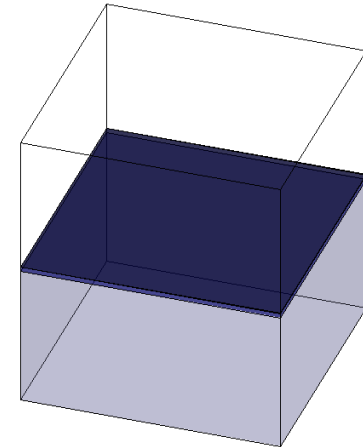
- **Create Radiation Boundary**
  - **To select the object Air**:
    - Select the menu item *Edit > Select > By Name*
    - Select Object Dialog,
      - Select the objects named: **Air**
      - Click the **OK** button
  - **To create a radiation boundary**
    - Select the menu item *HFSS > Boundaries > Assign > Radiation*
    - Radiation Boundary Window
      - Name: **Rad1**
      - Select: **Radiating Only**
      - Click the **OK** button

Example – Silicon Spiral Inductor

- **Create Ground**
  - **To create ground:**
    - Select the menu item ***Draw > Rectangle***
    - Using the coordinate entry fields, enter the box position
      - X: **-270.0**, Y: **-270.0**, Z: **0.0**, Press the Enter key
    - Using the coordinate entry fields, enter the opposite corner of the base rectangle:
      - dX: **540.0**, dY: **540.0**, dZ: **0.0**, Press the Enter key
  - To set the name:
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Ground**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item ***View > Fit All > Active View.***
      or press the **CTRL+D** key

WS04.1-11

Example – Silicon Spiral Inductor

- **Assign a Perfect E boundary to the Ground**
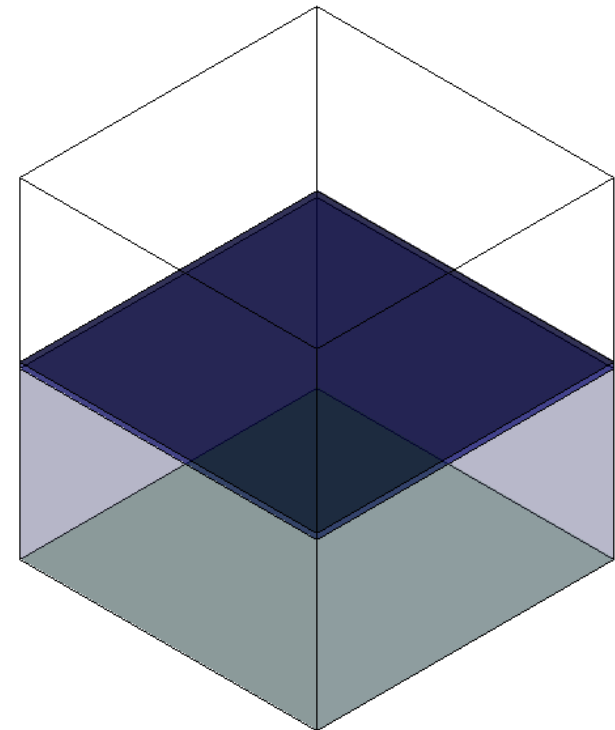   - **To select the ground:**
        - Select the menu item *Edit > Select > By Name*
        - Select Object Dialog,
            - Select the objects named: **Ground**
            - Click the **OK** button

    - **To assign the Perfect E boundary**
        - Select the menu item *HFSS > Boundaries > Assign > Perfect E*
        - Perfect E Boundary window
            - Name: **PerfE_Ground**
            - Infinite Ground Plane: ☐ **Unchecked**
            - Click the **OK** button

- **Hide Dielectrics**
    - **To hide the dielectrics:**
        - Select the menu item *Edit > Select All Visible*
        - Select the menu item *View > Hide Selection > All Views*
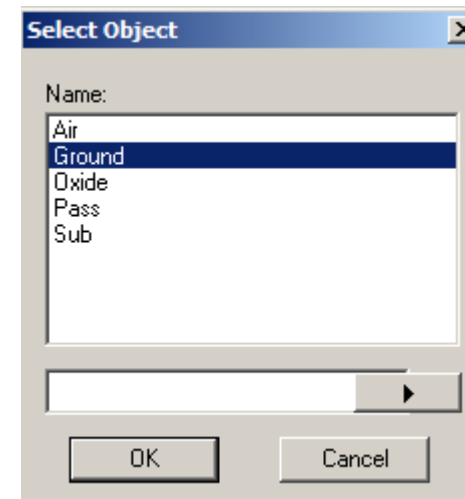
Example – Silicon Spiral Inductor

- **Set Default Material**
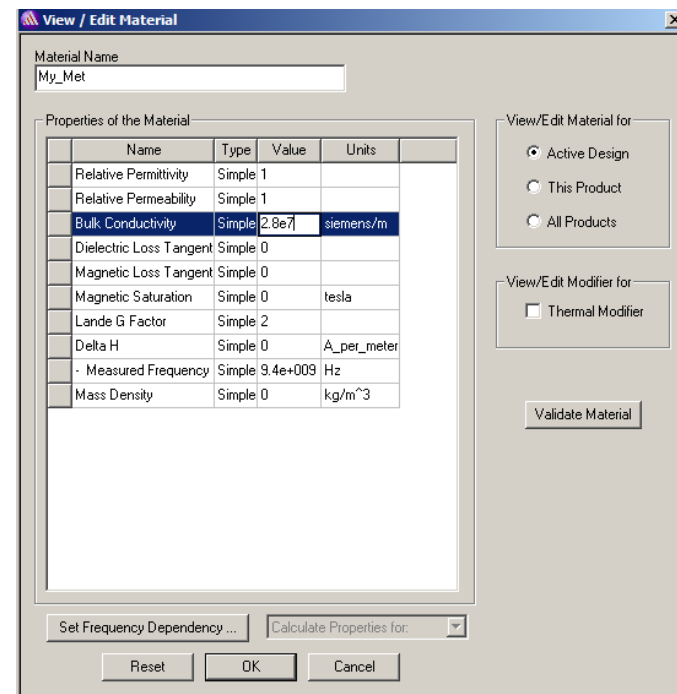 - **To set the default material:**
    - Using the 3D Modeler Materials toolbar, choose **Select**
    - Select Definition Window:
      - Click the **Add Material** button
      - View/Edit Material Window:
        - For the **Material Name** type: **My_Met**
        - For the **Value** of **Bulk Conductivity** type: **2.8e7**
        - Click the **OK** button
      - Click the **OK** button

- **Create Offset Coordinate System**
  - **To create an offset Coordinate System:**
    - Select the menu item *Modeler > Coordinate System > Create > Relative CS > Offset*
    - Using the coordinate entry fields, enter the origin
      - X: **0.0**, Y: **0.0**, Z: **304.8**, Press the **Enter** key

View / Edit Material

Material Name
My_Met

Properties of the Material

Name	Type	Value	Units
Relative Permittivity	Simple	1	
Relative Permeability	Simple	1	
Bulk Conductivity	Simple	2.8e7	siemens/m
Dielectric Loss Tangent	Simple	0	
Magnetic Loss Tangent	Simple	0	
Magnetic Saturation	Simple	0	tesla
Lande G Factor	Simple	2	
Delta H	Simple	0	A_per_meter
- Measured Frequency	Simple	9.4e+009	Hz
Mass Density	Simple	0	kg/m^3

View/Edit Material for
- ○ Active Design
- ○ This Product
- ○ All Products

View/Edit Modifier for
- ☐ Thermal Modifier

Validate Material

Set Frequency Dependency ...   Calculate Properties for:

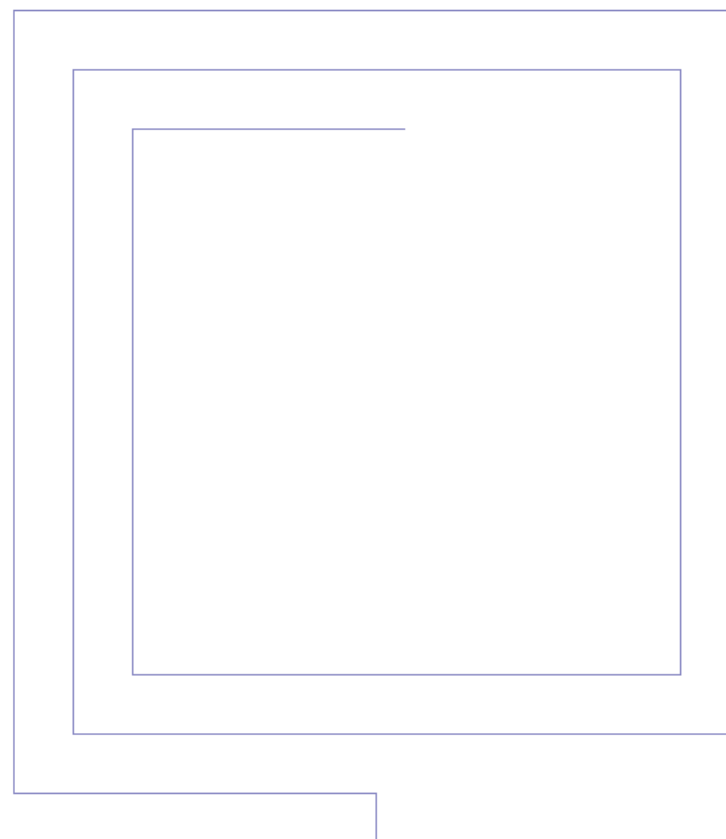Reset   OK   Cancel

Example – Silicon Spiral Inductor

- **Create Spiral Path**
  - **To create the path:**
    - Select the menu item *Draw > Line*
    - Using the coordinate entry fields, enter the vertex point:
      - X: **-67.5** , Y: **7.5**, Z: **1.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **-67.5** , Y: **-67.5** , Z: **1.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **84.0**, Y: **- 67.5**, Z: **1.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **84.0**, Y: **84.0**, Z: **1.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: - **84.0**, Y: **84.0**, Z: **1.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: - **84.0**, Y: **-84.0,** Z: **1.0** , Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **100.5** , Y: **-84.0**, Z: **1.0 ,** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **100.5** , Y: **100.5** , Z: **1.0** , Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: - **100.5** , Y: **100.5** , Z: **1.0 ,** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: - **100.5** , Y: **- 100.5**, Z: **1.0** , Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **117.0**, Y: -**100.5**, Z: **1.0** , Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **117.0**, Y: **0.0**, Z: **1.0** , Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **131.0**, Y: **0.0**, Z: **1.0** , Press the **Enter** key
   - Using the mouse, right-click and select **Done**

  - To set the name:
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Spiral**
    - Click the **OK** button when the Properties dialog appears

Example – Silicon Spiral Inductor

- **Create Spiral Path**

- **To assign trace width and thickness**
  - In Modeler Tree expand trace and click on **Create Polyline**
  - In Properties window change **Type** to **Rectangle**
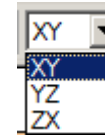 - Width: **15 um**
  - Height : **2 um**
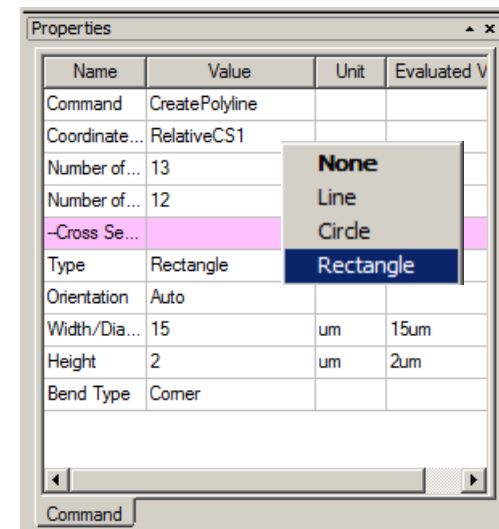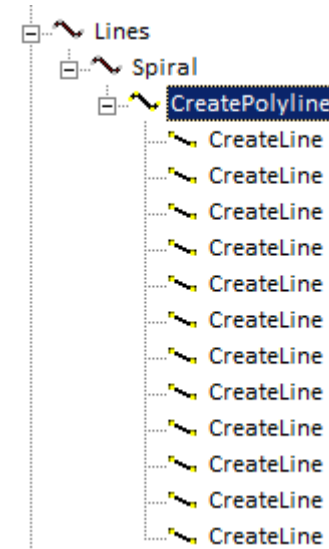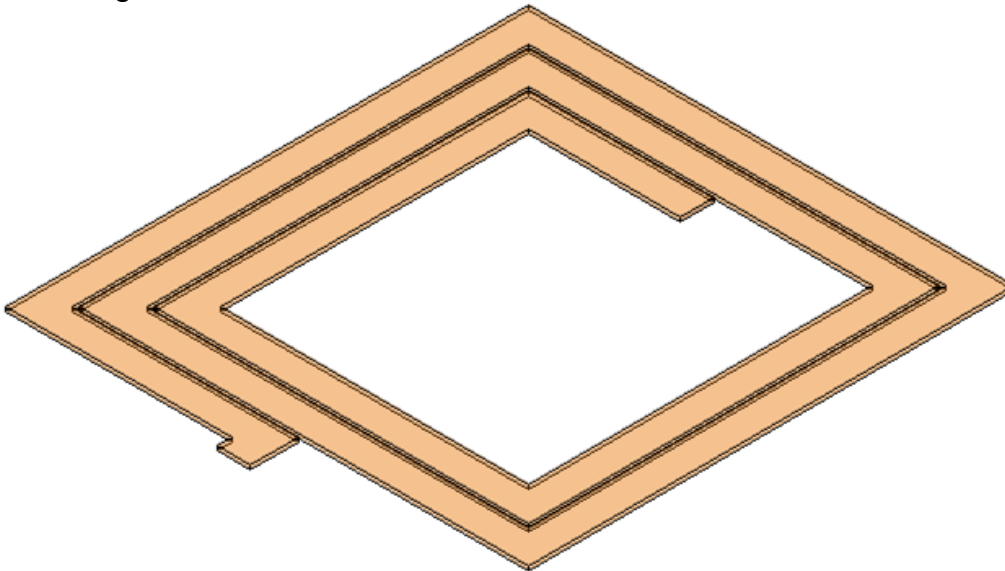
- **To fit the view:**
  Select the menu item **View > Fit All   > Active View.**
      Or press the **CTRL+D** key

Example – Silicon Spiral Inductor

- **Set Grid Plane**
  - **To set the grid plane:**
    - Select the menu item ***3D Modeler > Grid Plane > XY***

- **Create Underpass**
  - **To create underpass:**
    - Select the menu item ***Draw > Box***
    - Using the coordinate entry fields, enter the box position
      - X: **-60.0**, Y: **7.5**, Z: **-0.8**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **-75.0**, dY: **-15.0**, dZ: **-0.5**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Underpass**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item ***View > Fit All > Active View.***
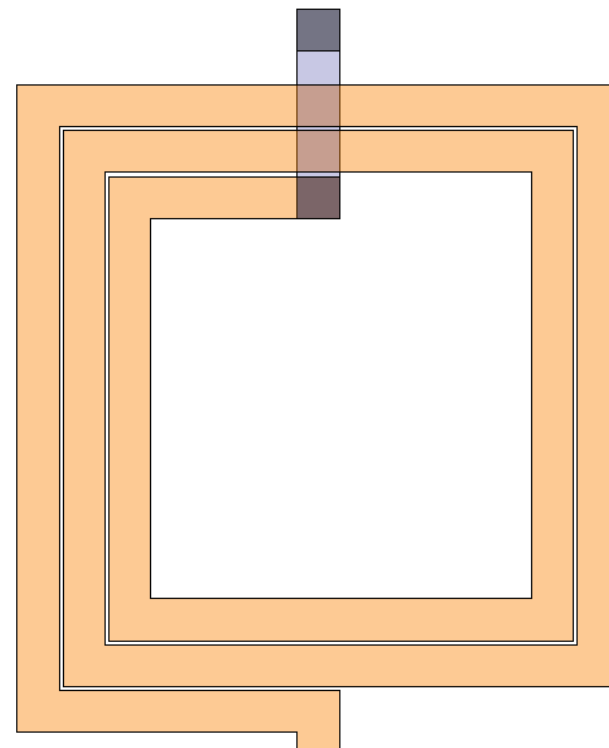   - Or press the **CTRL+D** key
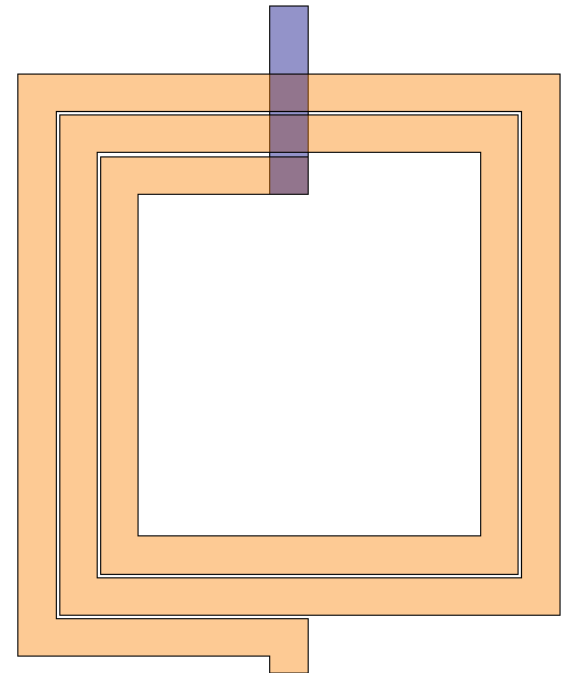
Example – Silicon Spiral Inductor

- **Create Via1**
  - **To create via:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-60.0**, Y: **7.5**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **-15.0**, dY: **-15.0**, dZ: **-0.8**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Via1**
    - Click the **OK** button

- **Create Via2**
  - **To create via:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-120.0**, Y: **7.5**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **-15.0**, dY: **-15.0**, dZ: **-0.8**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Via2**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View.*

Example – Silicon Spiral Inductor

- **Create Feed**
  - **To create feed:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-120.0**, Y: **7.5**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **-22.0**, dY: **-15.0**, dZ: **2.0**, Press the **Enter** key
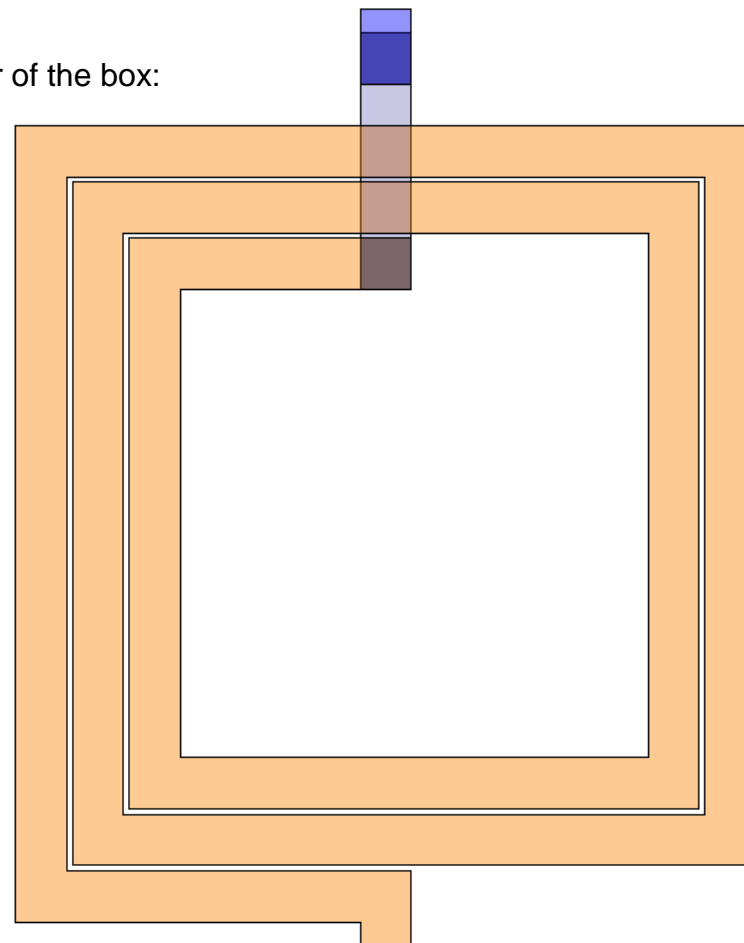 - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Feed**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View.*
    Or press the **CTRL+D** key

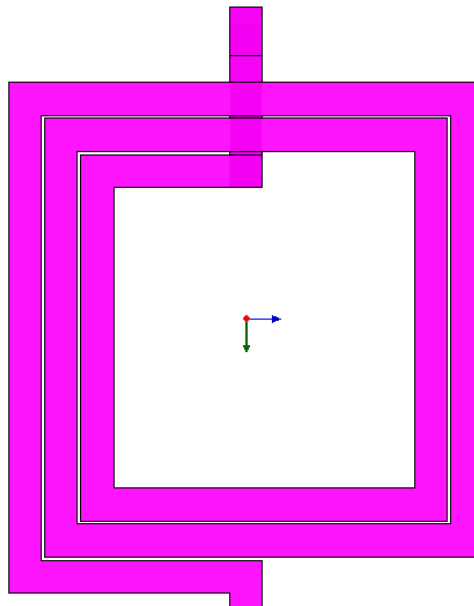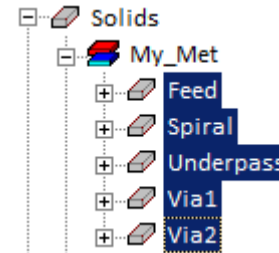# Example – Silicon Spiral Inductor

- **Unite Objects**
  - **To select spiral objects**
    - In the model tree, highlight: **Spiral**, and **Via1, Via2, Feed** and **Underpass**
    - Select the menu item **Modeler > Boolean > Unite**

- **To fit the view:**

  Select the menu item **View > Fit All   > Active View.**
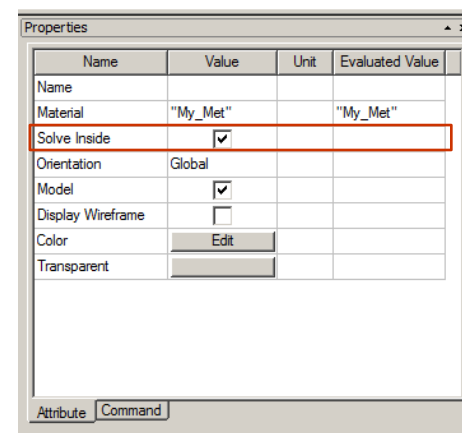   Or press the **CTRL+D** key

Example – Silicon Spiral Inductor

- **Solve Inside Conductors**
    - **To solve inside:**
        - Select the menu item **Edit > Select by Name**
        - Select Object Dialog,
            - Select: **Spiral**
        - Select the menu item **Edit > Properties**
        - Properties Dialog Attribute Tab
            - Solve Inside: ☑ **Checked**
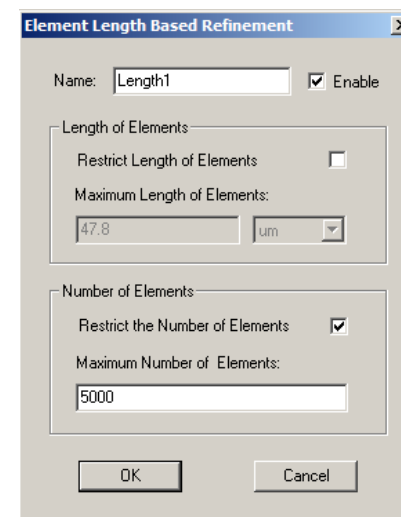   - Click the **OK** button

Name	Value	Unit	Evaluated Value
Name			
Material	"My_Met"		"My_Met"
Solve Inside	☑		
Orientation	Global		
Model	☑		
Display Wireframe	☐		
Color	Edit		
Transparent			

Attribute | Command

    - Click the **OK** button for all warning messages (Solving inside a solid with high conductivity may require a large mesh)

- **Seed Mesh Conductors set for Solve Inside**
    - **To solve inside:**
        - Select the menu item **Edit > Select All Visible**
        - Select the menu item **HFSS > Mesh Operations >**
        Assign > Inside Selection > Length Based
        - Element Length Based Refinement Dialog
            - Name**: Length1**
            - Restrict Length of Elements: ☐ **Unchecked**
            - Restrict Number of Elements: ☑ **Checked**
            - Maximum Number of Elements**: 5000**
            - Click the **OK** button

Element Length Based Refinement

Name: Length1   ☑ Enable

Length of Elements
  Restrict Length of Elements   ☐
  Maximum Length of Elements:
  47.8   um

Number of Elements
  Restrict the Number of Elements   ☑
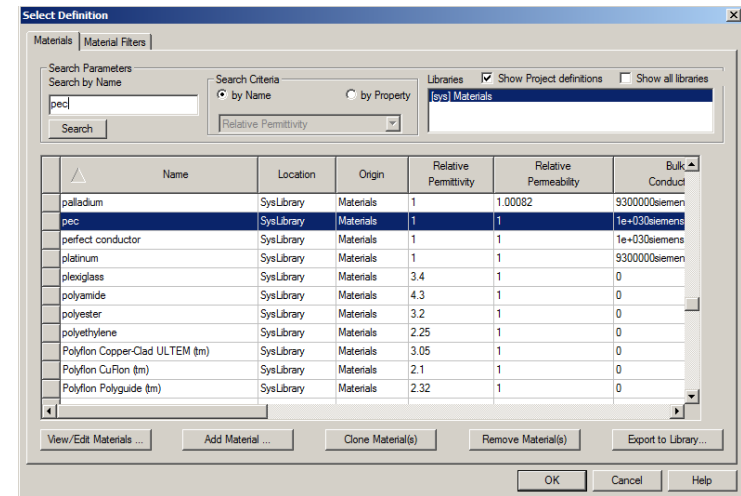 Maximum Number of Elements:
  5000

OK   Cancel

Example – Silicon Spiral Inductor

- **Set Default Material**
  - **To set the default material:**
    - Using the 3D Modeler Materials toolbar, choose **Select**
    - Select Definition Window:
      - Type **pec** in the **Search by Name** field
      - Click the **OK** button

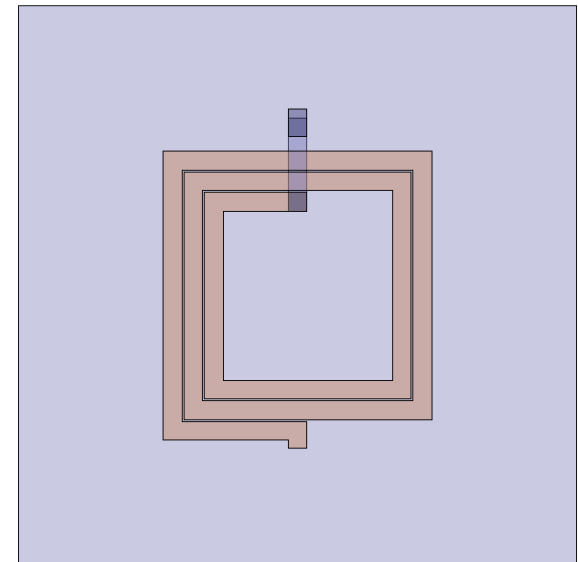- **Create Ground Ring**
  - **To create outer ring:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-225.0**, Y: **-225.0**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **450.0**, dY: **450.0**, dZ: **2.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Ring**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View*

Example – Silicon Spiral Inductor

- **Create Inner Ring**
  - **To create inner ring:**
    - Select the menu item ***Draw > Box***
    - Using the coordinate entry fields, enter the box position
      - X: **-210.0**, Y: **-210.0**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **420.0**, dY: **420.0**, dZ: **2.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Inner**
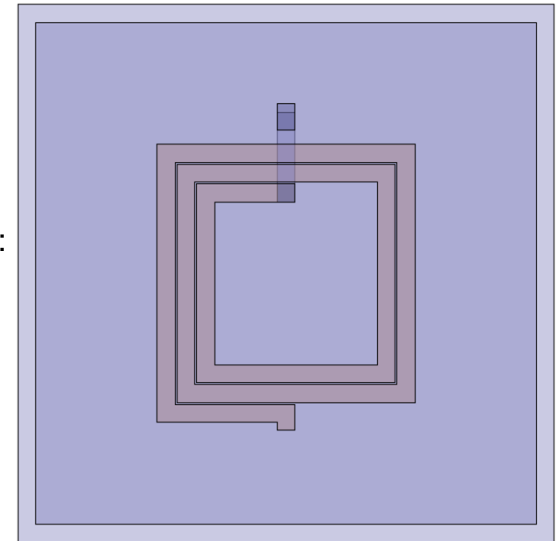   - Click the **OK** button
  - **To fit the view:**
    - Select the menu item ***View > Fit All > Active View***

- **Complete the Ring**
 - **To select the objects Ring and Inner:**
    - Select the menu item ***Edit > Select > By Name***
    - Select Object Dialog,
      - Select the objects named: **Ring, Inner**
      - Click the **OK** button
  - **To complete the ring:**
    - Select the menu item ***Modeler > Boolean > Subtract***
    - Subtract Window
      - Blank Parts: **Ring**
      - Tool Parts: **Inner**
      - Click the **OK** button
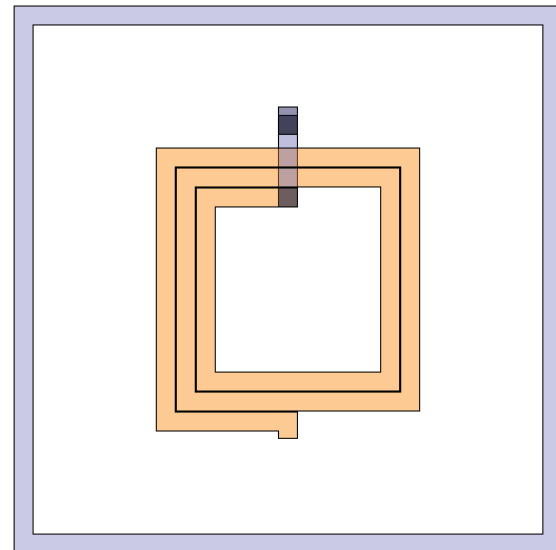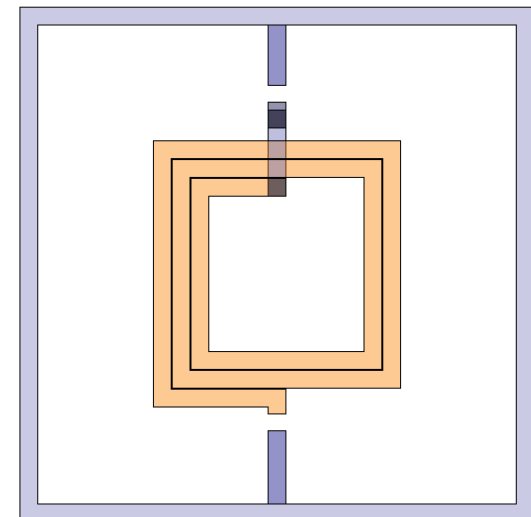
Example – Silicon Spiral Inductor

- **Create Extension 1**
  - **To create extension:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **-157.0**, Y: **7.5**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **-53.0**, dY: **-15.0**, dZ: **2.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Ring_Ext1**
    - Click the **OK** button
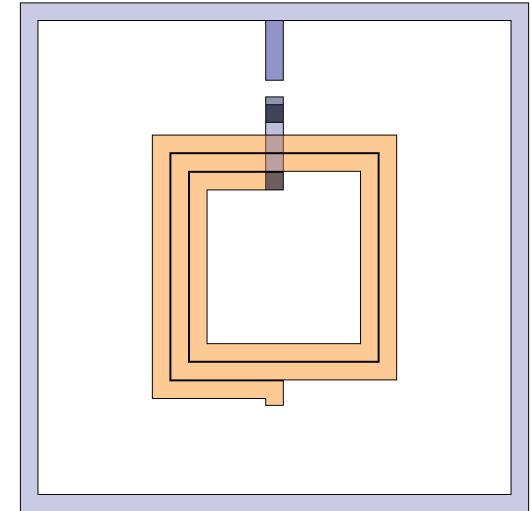
- **Create Extension 2**
  - **To create extension:**
    - Select the menu item *Draw > Box*
    - Using the coordinate entry fields, enter the box position
      - X: **146.0**, Y: **7.5**, Z: **0.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the box:
      - dX: **64.0**, dY: **-15.0**, dZ: **2.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Ring_Ext2**
    - Click the **OK** button
  - **To fit the view:**
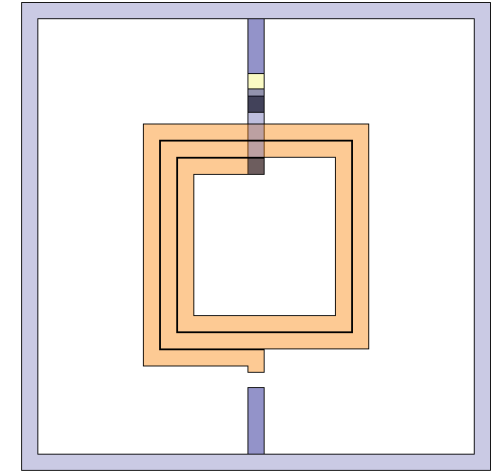   - Select the menu item *View > Fit All > Active View*

Example – Silicon Spiral Inductor

- **Create Source 1**
  - **To create source:**
    - Select the menu item *Draw > Rectangle*
    - Using the coordinate entry fields, enter the box position
      - X: **-142.0**, Y: **7.5**, Z: **1.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the base rectangle:
      - dX: **-15.0**, dY: **-15.0**, dZ: **0.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Source1**
    - Click the **OK** button
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View.*


- **Create Source 2**
  - **To create source:**
    - Select the menu item *Draw > Rectangle*
    - Using the coordinate entry fields, enter the box position
      - X: **131.0**, Y: **7.5**, Z: **1.0**, Press the **Enter** key
    - Using the coordinate entry fields, enter the opposite corner of the base rectangle:
      - dX: **15.0**, dY: **-15.0**, dZ: **0.0**, Press the **Enter** key
  - **To set the name:**
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Source2**
    - Click the **OK** button
  - **To fit the view:**
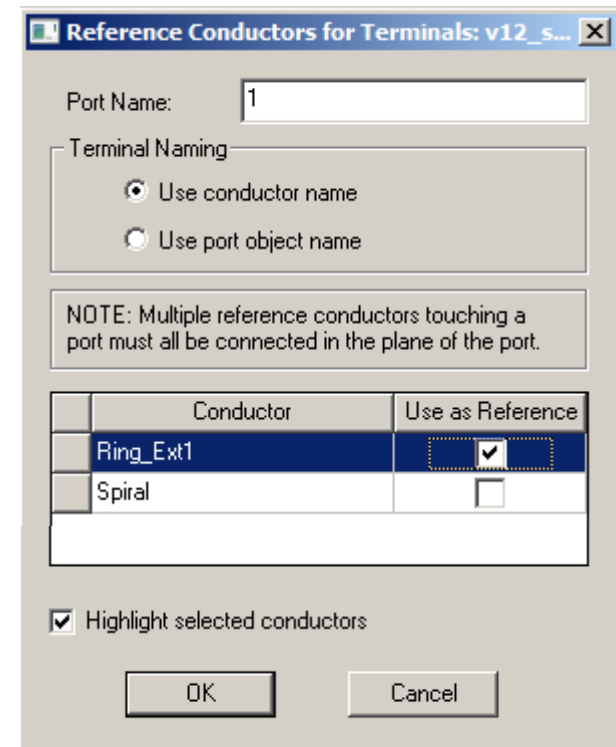   - Select the menu item *View > Fit All > Active View.*
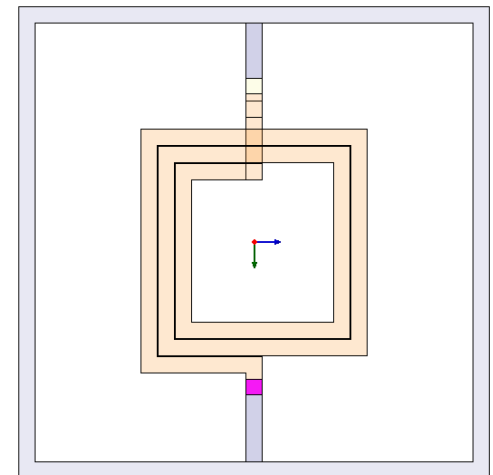
Example – Silicon Spiral Inductor

- **Group the Conductors**
  - **To group the conductors:**
    - Select the menu item *Edit > Select > By Name*
    - Select Object Dialog,
      - Select the objects named: **Ring, Ring_Ext1, Ring_Ext2**
      - Click the **OK** button
    - Select the menu item, *Modeler > Boolean > Unite*
  - **To fit the view:**
    - Select the menu item *View > Fit All > Active View***.**

- **Assign Excitation**
  - **To select the object Source:**
    - Select the menu item *Edit > Select > By Name*
    - Select Object Dialog,
      - Select the objects named: **Source1**
      - Click the **OK** button
    - **Note**: You can also select the object from the Model Tree
  - **To assign lumped port excitation**
    - Select the menu item *HFSS > Excitations > Assign > Lumped Port*
    - Lumped Port : General
      - Port Name: **1**,
      - Conductor: **Ring _Ext1**
      - Use as Reference: ☑ **Checked**
    - Highlight Selected conductors: ☑ **Checked**
    - Click **OK**

Reference Conductors for Terminals: v12_s... ☒

Port Name: | 1 |

Terminal Naming
- ◉ Use conductor name
- ○ Use port object name

NOTE: Multiple reference conductors touching a port must all be connected in the plane of the port.

	Conductor	Use as Reference
	Ring_Ext1	☑
	Spiral	☐

☑ Highlight selected conductors

| OK | | Cancel |

Example – Silicon Spiral Inductor
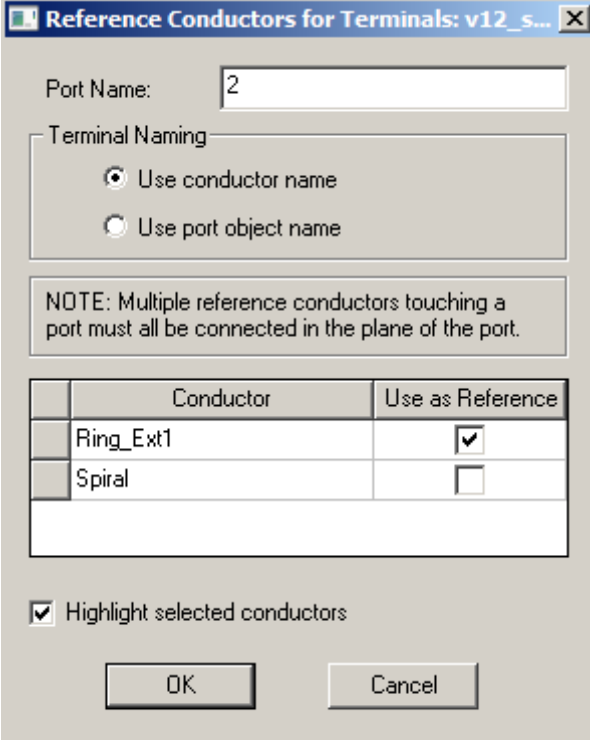
- **Assign Excitation**
  - **To select the object Source:**
    - Select the menu item *Edit > Select > By Name*
    - Select Object Dialog,
      - Select the objects named: **Source1**
      - Click the **OK** button
    - **Note**: You can also select the object from the Model Tree
  - **To assign lumped port excitation**
    - Select the menu item *HFSS > Excitations > Assign > Lumped Port*
    - Lumped Port : General
      - Port Name: **2**,
      - Conductor: **Ring _Ext1**
      - Use as Reference: ☑ **Checked**
    - Highlight Selected conductors: ☑ **Checked**
    - Click **OK**

- **Show All**
  - **To show all object**
    - Select the menu item *View > Show All > All Views*

Example – Silicon Spiral Inductor

- **Assign Excitation**
  - **To select the object Source:**
    - Select the menu item ***Edit > Select > By Name***
    - Select Object Dialog,
      - Select the objects named: **Source1**
      - Click the **OK** button
    - **Note**: You can also select the object from the Model Tree
  - **To assign lumped port excitation**
    - Select the menu item ***HFSS > Excitations > Assign > Lumped Port***
    - Lumped Port : General
      - Port Name: **1**,
      - Conductor: **Ring _Ext1**
        - Use as Reference: ☑ **Checked**
    - Highlight Selected conductors: ☑ **Checked**
    - Click **OK**

Reference Conductors for Terminals: v12_s...

Port Name: `1`

Terminal Naming
- ● Use conductor name
- ○ Use port object name

NOTE: Multiple reference conductors touching a port must all be connected in the plane of the port.

Conductor	Use as Reference
Feed	☐
Ring_Ext1	☑

☑ Highlight selected conductors

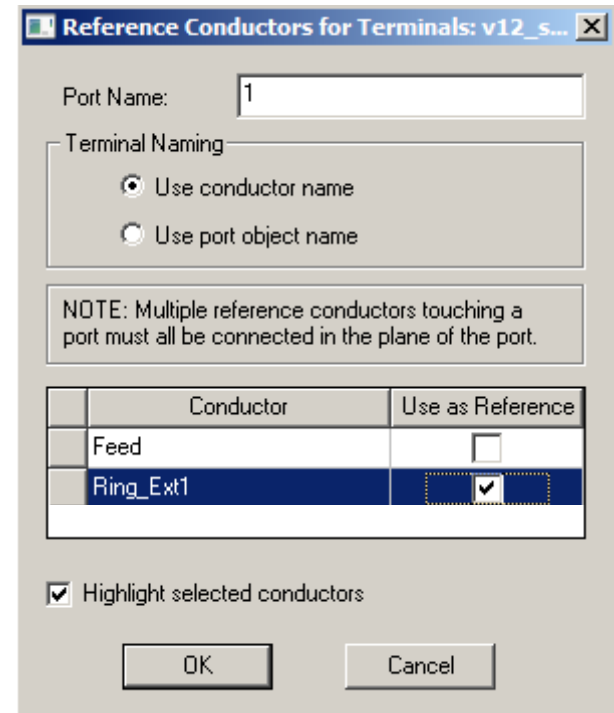OK   Cancel

Example – Silicon Spiral Inductor

- **Assign Excitation**
  - **To select the object Source:**
    - Select the menu item *Edit > Select > By Name*
    - Select Object Dialog,
      - Select the objects named: **Source1**
      - Click the **OK** button
    - **Note**: You can also select the object from the Model Tree
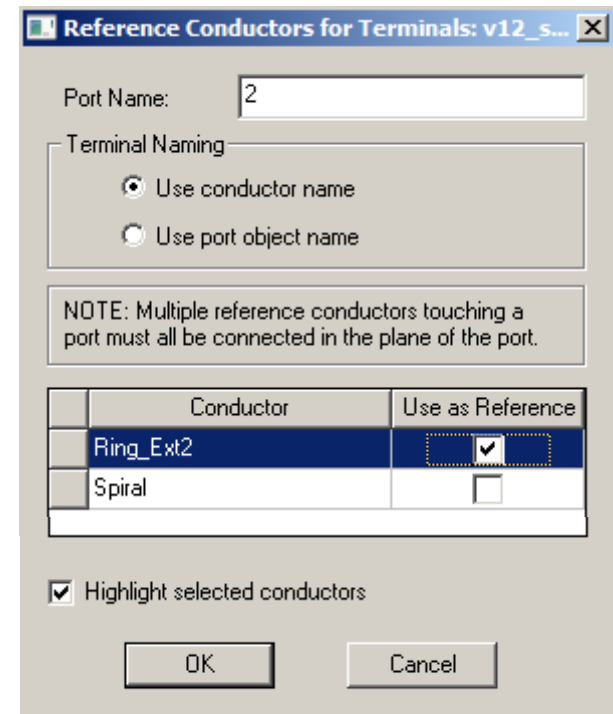 - **To assign lumped port excitation**
    - Select the menu item *HFSS > Excitations > Assign > Lumped Port*
    - Lumped Port : General
      - Port Name: **2**,
      - Conductor: **Ring _Ext2**
        - Use as Reference: ☑ **Checked**
    - Highlight Selected conductors: ☑ **Checked**
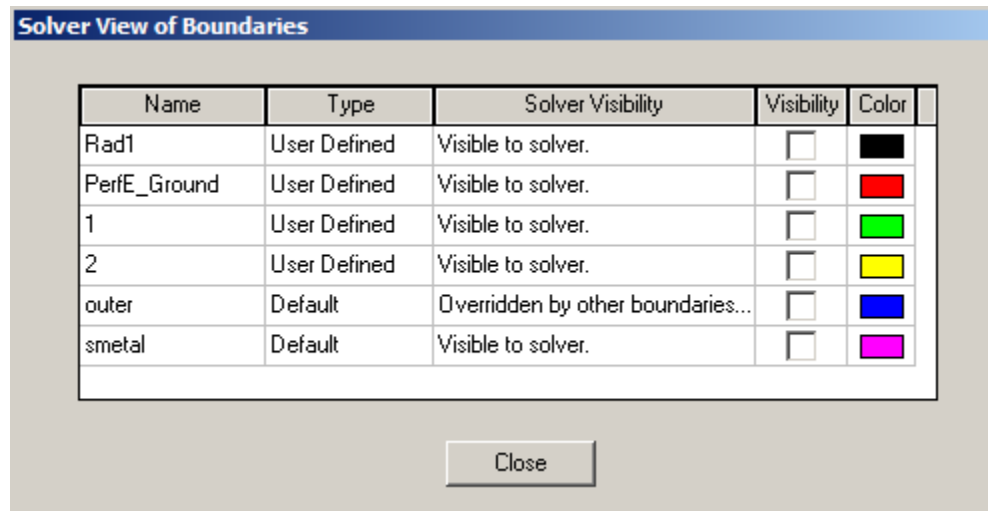   - Click **OK**

Reference Conductors for Terminals: v12_s... ✕

Port Name: [2]

Terminal Naming
- ◉ Use conductor name
- ○ Use port object name

NOTE: Multiple reference conductors touching a port must all be connected in the plane of the port.

Conductor	Use as Reference
Ring_Ext2	☑
Spiral	☐

☑ Highlight selected conductors

[OK]   [Cancel]

- **Show All**
  - **To show all object**
    - Select the menu item *View > Show All > All Views*

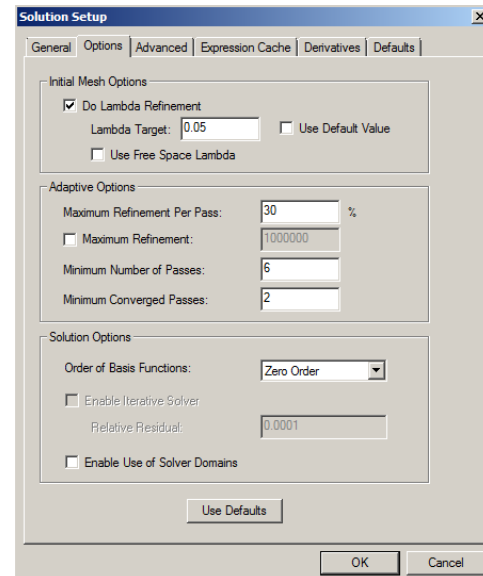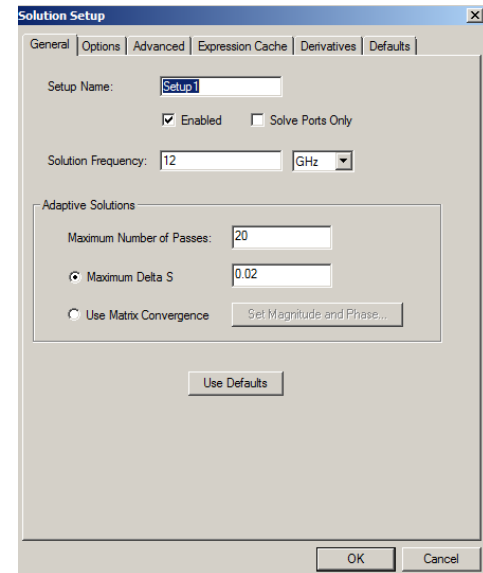# Example – Silicon Spiral Inductor

- **Boundary Display**
  - **To verify the boundary setup:**
    - Select the menu item *HFSS > Boundary Display (Solver View)*
    - From the Solver View of Boundaries, toggle the Visibility check box for the boundaries you wish to display.
      - **Note:** The background (Perfect Conductor) is displayed as the **outer** boundary.
      - **Note:** The Perfect Conductors are displayed as the **smetal** boundary.
      - **Note:** Select the menu item, *View > Visibility* to hide all of the geometry objects. This makes it easier to see the boundary
   - Click the **Close** button when you are finished

Solver View of Boundaries

Name	Type	Solver Visibility	Visibility	Color
Rad1	User Defined	Visible to solver.	☐	■
PerfE_Ground	User Defined	Visible to solver.	☐	■
1	User Defined	Visible to solver.	☐	■
2	User Defined	Visible to solver.	☐	■
outer	Default	Overridden by other boundaries…	☐	■
smetal	Default	Visible to solver.	☐	■

Close

Example – Silicon Spiral Inductor

- **Analysis Setup**

- **Creating an Analysis Setup**
  - **To create an analysis setup:**
    - Select the menu item *HFSS > Analysis Setup > Add Solution Setup*
    - Solution Setup Window:
      - Click the **General** tab**:**
        - Solution Frequency**: 12.0GHz**
        - Maximum Number of Passes: **20**
        - Maximum Delta S: **0.02**
      - Click the **Options** tab**:**
        - Do Lambda Refinement: ☑ **Checked**
        - Lambda Target**: 0.05**
        - Maximum Refinement per pass: **30%**
        - Minimum Number of Passes: **6**
        - Minimum Number of Converged Passes: **2**
        - Order of Basis Function: **Zero Order**
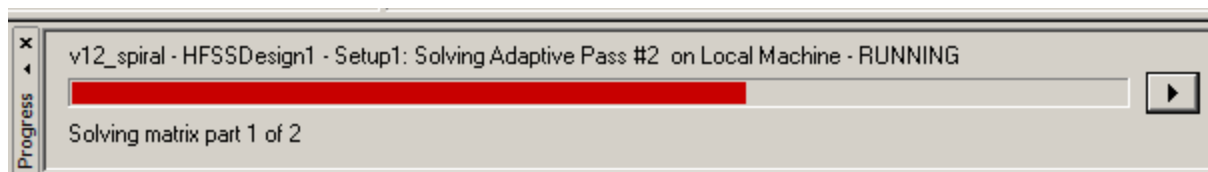   - Click the **OK** button

Example – Silicon Spiral Inductor

- **Analysis Setup**

- **Adding a Frequency Sweep**
  - **To add a frequency sweep:**
    - Select the menu item *HFSS > Analysis Setup > Add Sweep*
      - Select Solution Setup: **Setup1**
      - Click the **OK** button
    - Edit Sweep Window:
      - Sweep Type**: Interpolating**
      - Frequency Setup Type**: Linear Step**
        - Start: **0.1GHz**
        - Stop**: 20.0GHz**
        - Step**: 0.1GHz**
      - Interpolating Sweep Options
        - Max Solutions**: 50**
        - Error Tolerance**: 0.1%**

      - Click the **OK** button
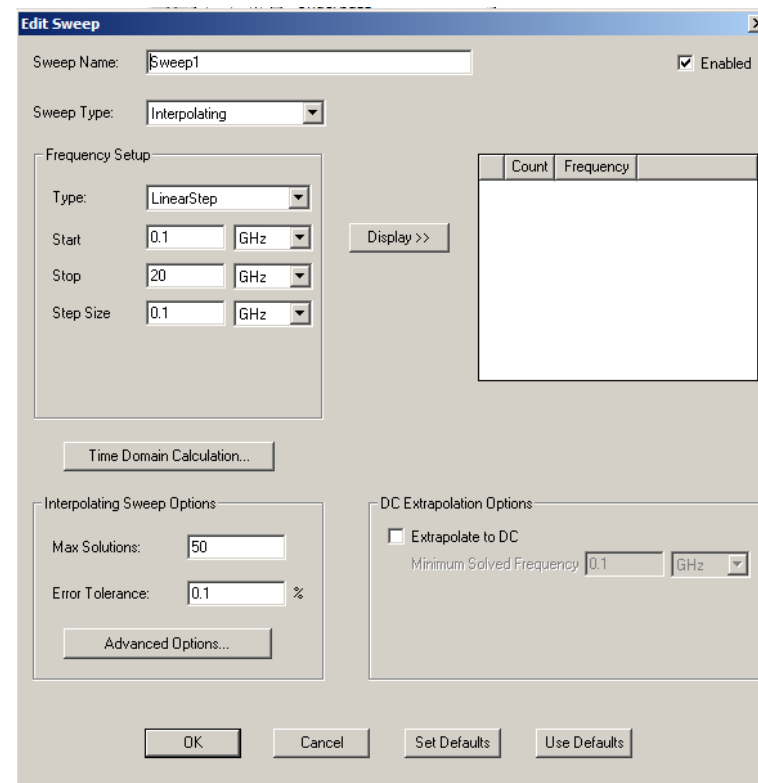
Example – Silicon Spiral Inductor

- **Save Project**
  - **To save the project:**
    - In an Ansoft HFSS window, select the menu item *File > Save As*.
    - From the **Save As** window, type the Filename: **hfss_spiral_inductor**
    - Click the **Save** button

- **Analyze**

- **Model Validation**
  - **To validate the model:**
    - Select the menu item *HFSS > Validation Check*
    - Click the **Close** button
      - **Note:** To view any errors or warning messages, use the Message Manager.

- **Analyze**
  - **To start the solution process:**
    - Select the menu item *HFSS > Analyze All*

---

v12_spiral - HFSSDesign1 - Setup1: Solving Adaptive Pass #2 on Local Machine - RUNNING

Progress

Solving matrix part 1 of 2

Example – Silicon Spiral Inductor

- **Solution Data**
    - **To view the Solution Data:**
        - Select the menu item *HFSS > Results > Solution Data*
            - **To view the Profile:**
                - Click the **Profile** Tab.
            - **To view the Convergence:**
                - Click the **Convergence** Tab
                - **Note:** The default view is for convergence is **Table**. Select the **Plot** radio button to view a graphical representations of the convergence data.
            - **To view the Matrix Data:**
                - Click the **Matrix Data** Tab
                - **Note:** To view a real-time update of the Matrix Data, set the Simulation to **Setup1, Last Adaptive**
        - Click the **Close** button
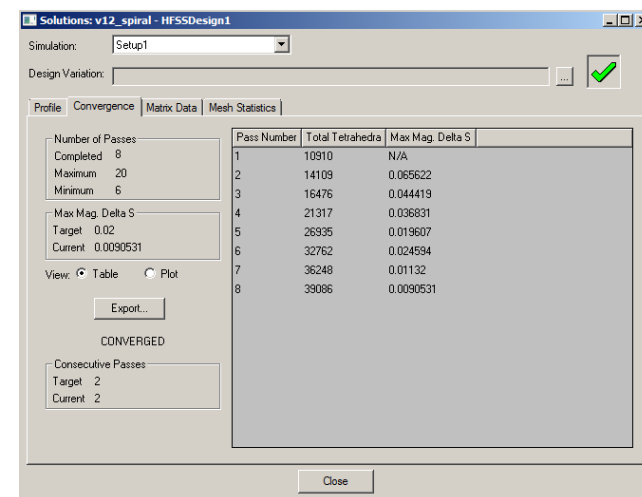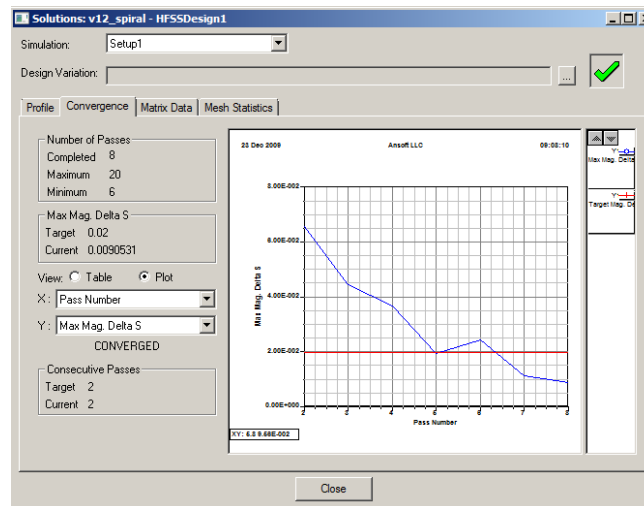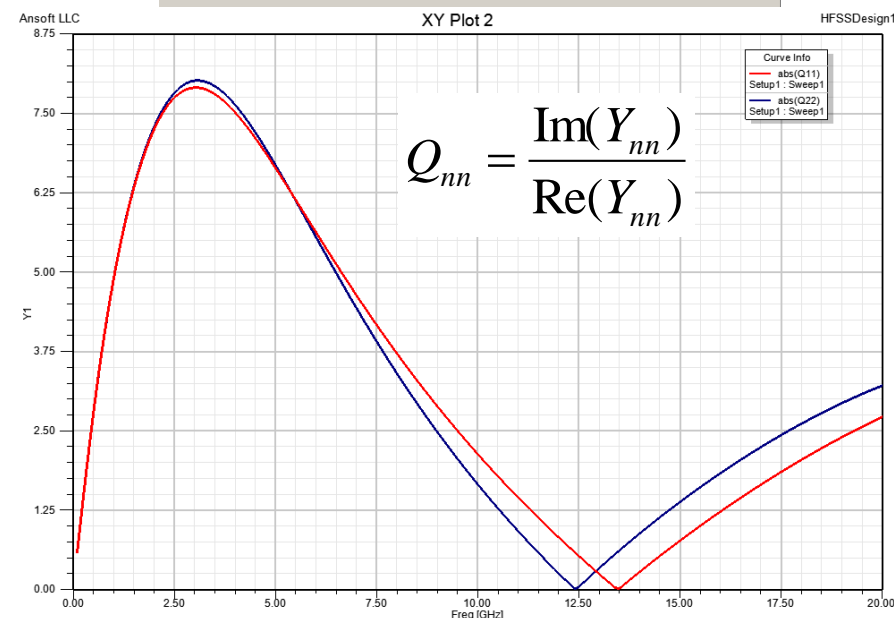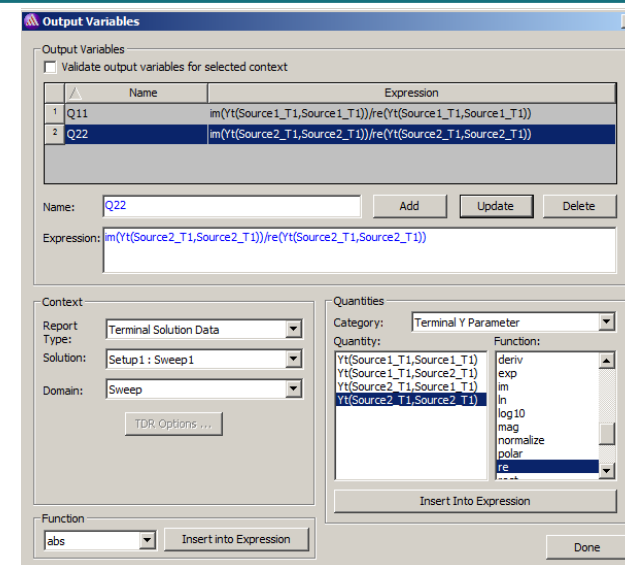
Example – Silicon Spiral Inductor

- **Create Reports**

- **Create S-parameter vs. Frequency**
  - **To Create a report:**
    - Select the menu item ***HFSS > Results > Create Report***
    - Create Report Window**:**
      - Report Type: **Terminal S Parameters**
      - Display Type: **Rectangular**
      - Click the **OK** button
    - Traces Window**:**
      - Solution: **Setup1: Sweep1**
      - Click the **Y** tab
        - Domain: **Sweep**
        - Category: **Terminal S-Parameters**
        - Quantity: **St(Source1_T1, Source1_T1)** and **St(Source1_T1, Source2_T1)**
        - Function: **dB**
        - Click the **Add Trace** button
      - Click the **Done** button
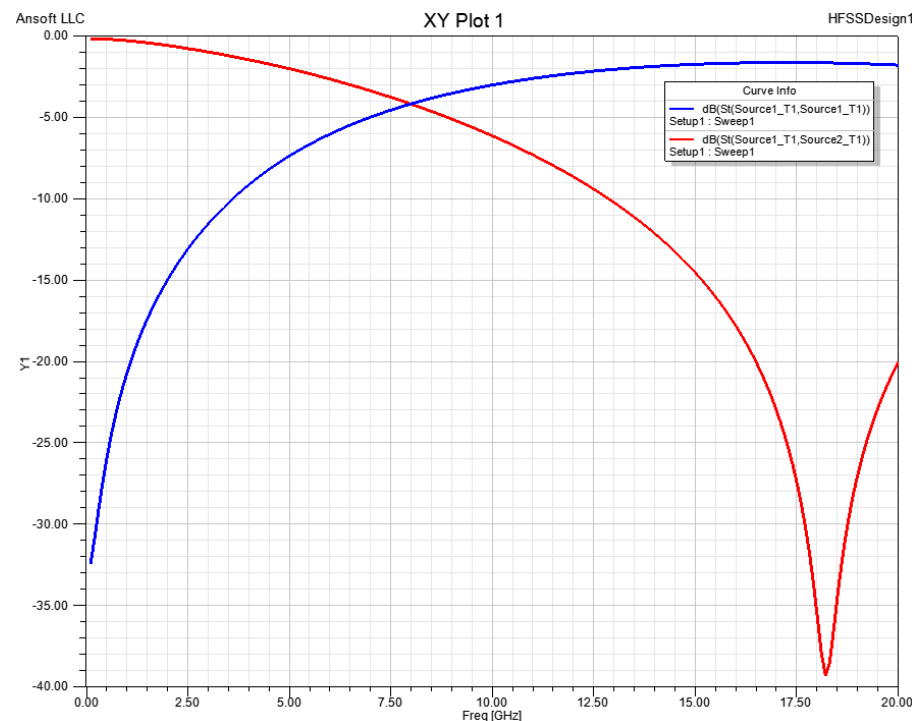
Example – Silicon Spiral Inductor

- **Custom Equations – Output Variables**
    - Select the menu item *HFSS > Results > Create Report*
    - Create Report Window**:**
        - Report Type: **Terminal S Parameters**
        - Display Type: **Rectangular**
        - Click the **OK** button
    - **Traces Window:**
        - Click the **Output Variables** button
    - **Output Variables dialog:**
        - Name: **Q11**
        - Expression:
            - Category: **Terminal Y Parameters**
            - Quantity: **Yt(Source1_T1, Source1_T1)**
            - Function: **im**
            - Click the **Insert Quantity into Expression** button
            - Type: **/**
            - Quantity: **Yt(Source1_T1, Source1_T1)**
            - Function: **re**
            - Click the **Insert Quantity into Expression** button
        - Click the **Add** button
        - Repeat for **Q22**, by replacing **Yt(Source1_T1, Source1_T1)** with **Yt(Source2_T1, Source2_T1)**
        - Click the **Done** button
    - Solution: **Setup1: Sweep1**
        - Domain: **Sweep**
            - Category: **Output Variables**
            - Quantity: **Q11, Q22**
            - Function: **abs**
   - Click the **New report** button
        - Click **Close** button

$$Q_{nn} = \frac{\text{Im}(Y_{nn})}{\text{Re}(Y_{nn})}$$

Example – Silicon Spiral Inductor

- **Create Reports (Continued)**
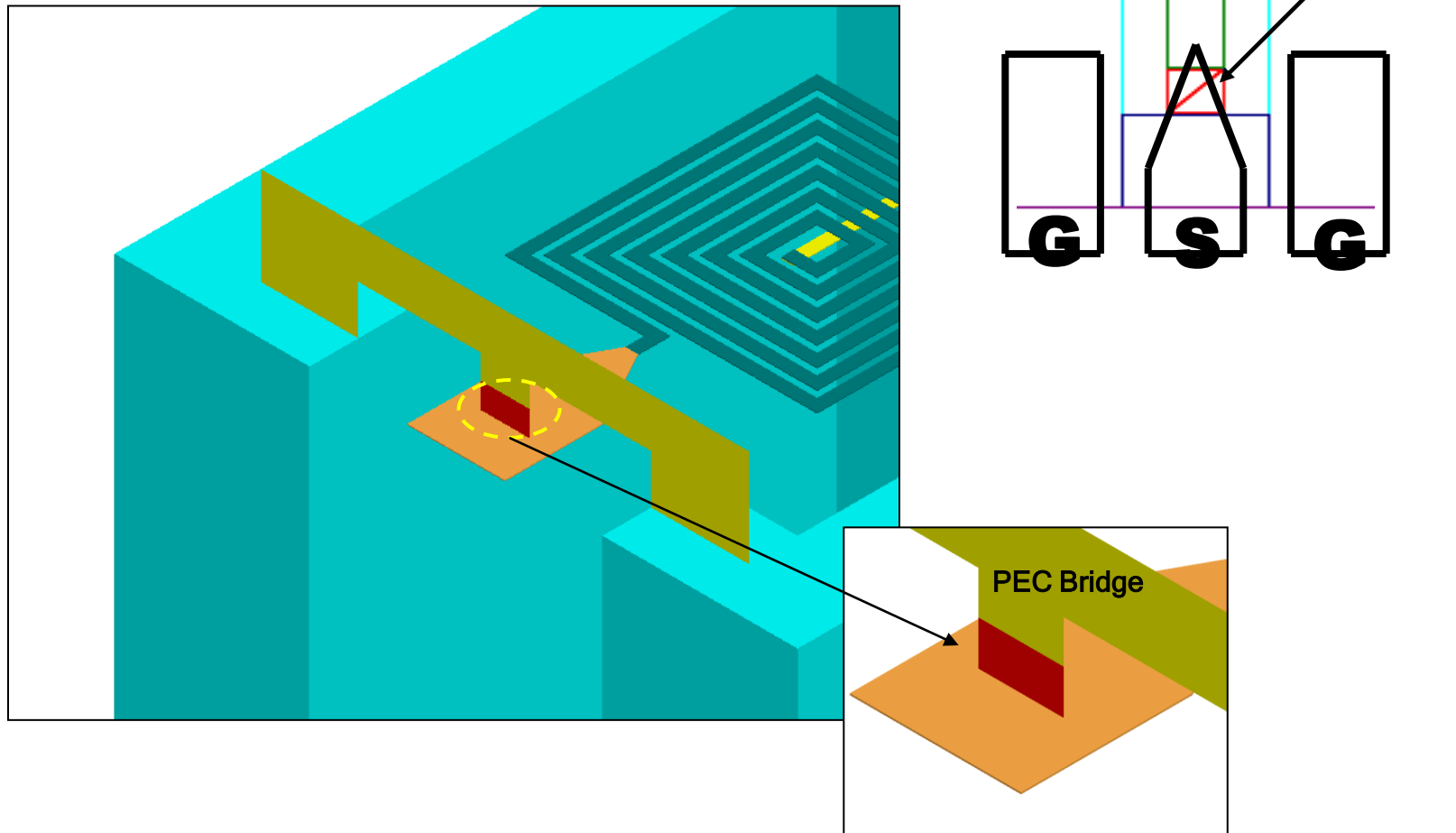- **Custom Equations – Output Variables**
    - Select the menu item *HFSS > Results > Create Report*
    - Create Report Window**:**
        - Report Type: **Terminal S Parameters**
        - Display Type: **Rectangular**
        - Click the **OK** button
    - Traces Window**:**
        - Click the **Output Variables** button
        - Output Variables dialog:
            - Name: **L11**
            - Expression:
                - Type: **-1/(2*pi*freq***
                - Category: **Terminal Y Parameters**
                - Quantity: **Yt(Source1_T1, Source1_T1)**
                - Function: **im**
                - Click the **Insert Quantity into Expression** button
                - Type: **)**
            - Click the **Add** button
            - Click the **Done** button
        - Solution: **Setup1: Sweep1**
        - Domain: **Sweep**
        - Click the **Y** tab
            - Category: **Output Variables**
            - Quantity: **Y11**
            - Function: **none**
            - Click the **New Report** button
        - Click **Close** button
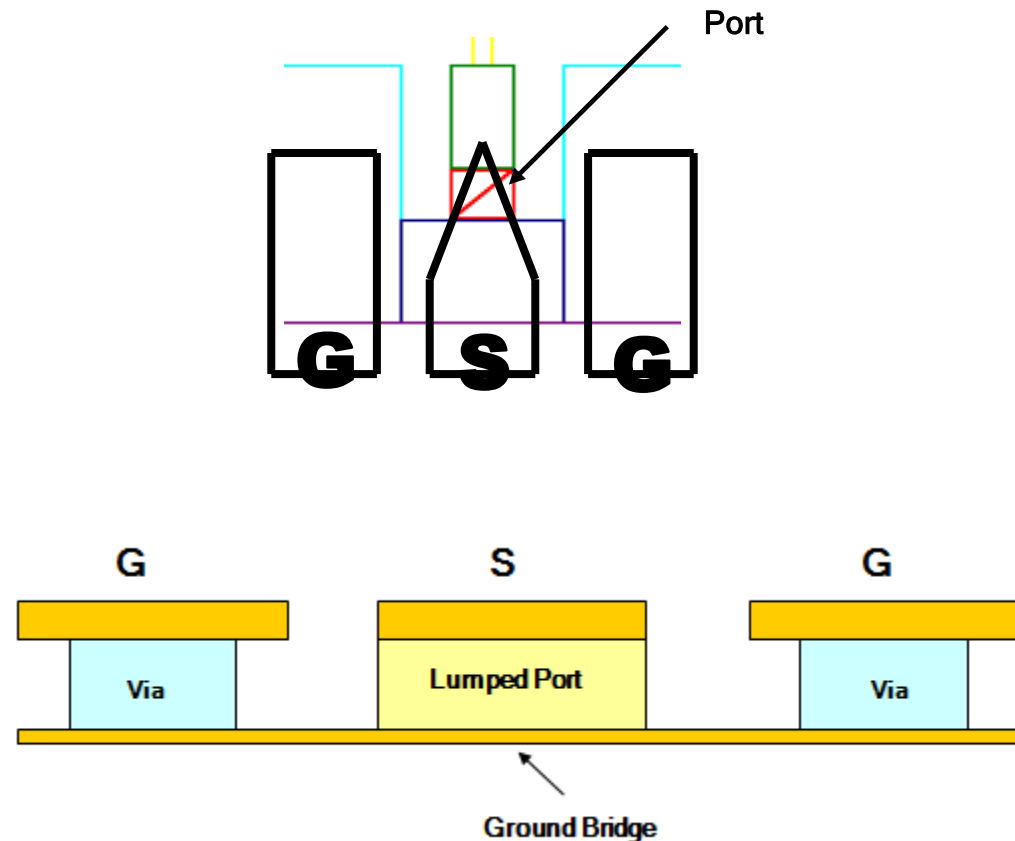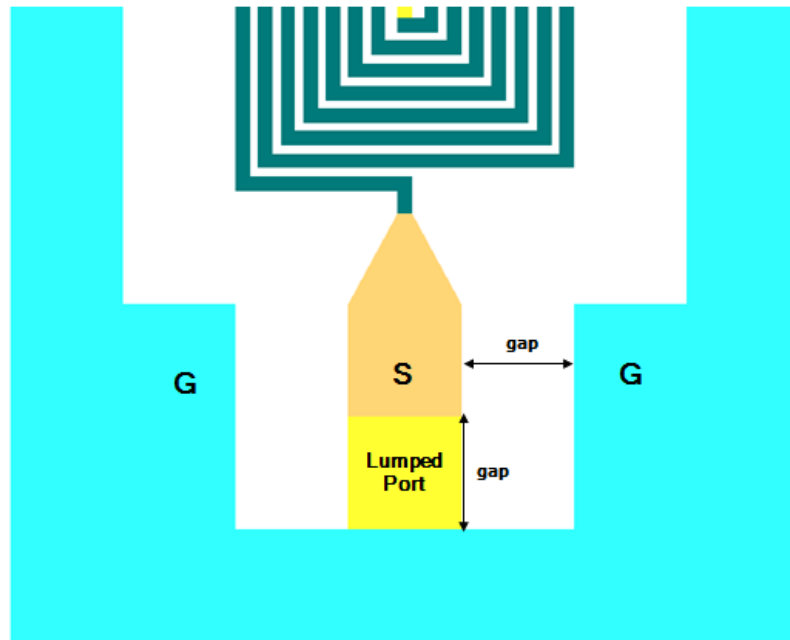
$$L_{nn} = \frac{-1}{2\pi \cdot f \cdot im(Y_{nn})}$$
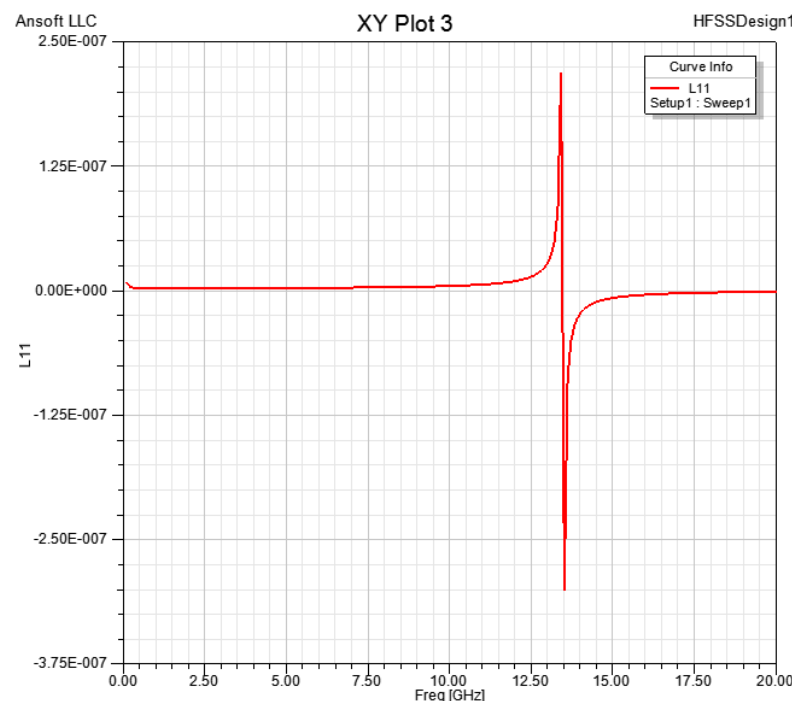
Example – Silicon Spiral Inductor

- **Appendix – Alternative Lumped Ports**

Port

G   S   G

PEC Bridge

- **Appendix – Alternative Lumped Ports**

Example – Silicon Spiral Inductor

- **Create Spiral Ring**
  - **To create the path:**
    - Select the menu item ***Draw > Line***
    - Using the coordinate entry fields, enter the vertex point:
      - X: **-217.5** , Y: **-217.5,** Z: **2.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **-217.5** , Y: **217.5,** Z: **2.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **217.5** , Y: **217.5,** Z: **2.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **217.5** , Y: -**217.5,** Z: **2.0** Press the **Enter** key
    - Using the coordinate entry fields, enter the vertex point:
      - X: **-217.5** , Y: -**217.5,** Z: **2.0** Press the **Enter** key

    1. Using the mouse, right-click and select **Done**
  - To set the name:
    - Select the **Attribute** tab from the **Properties** window.
    - For the **Value** of **Name** type: **Ring**
    1. Click the **OK** button when the Properties dialog appears