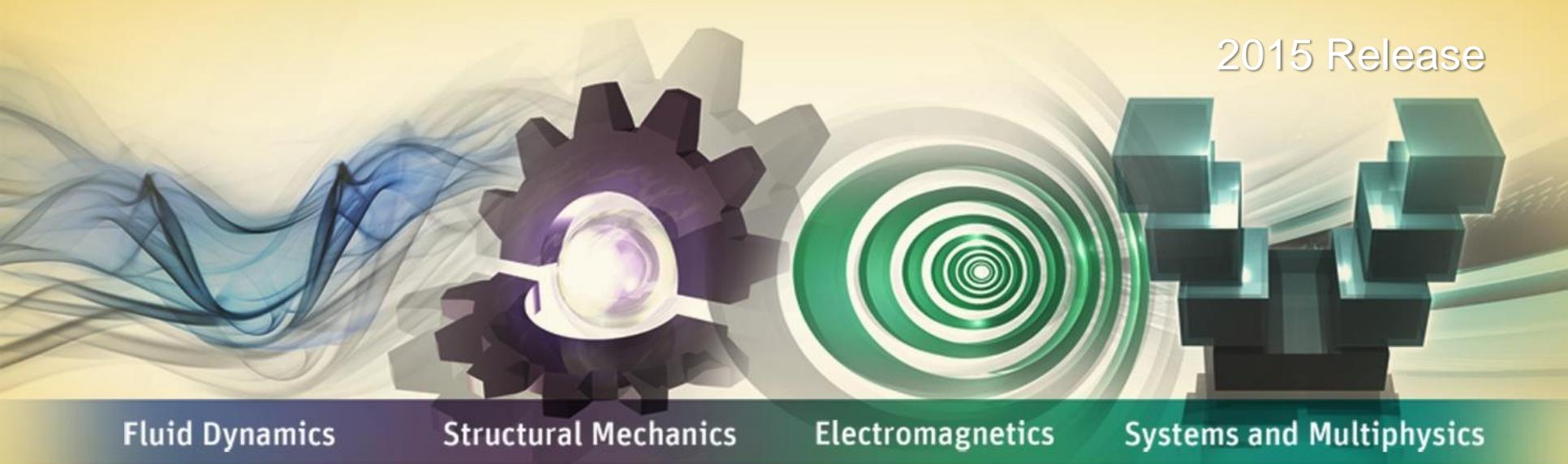


# Workshop 3: Q3D 2D Extractor – Transmission Line Toolkit

2015 Release



Fluid Dynamics

Structural Mechanics

Electromagnetics

Systems and Multiphysics

## Stripline Transmission Line 2D Extractor Simulation

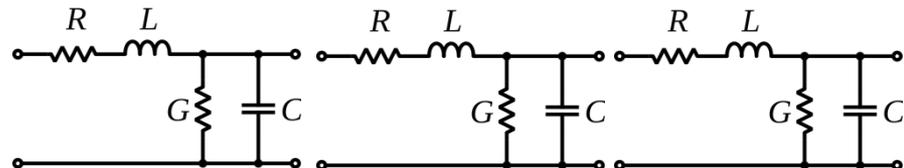
## • 2D Extractor Topics to be Covered:

- Creating a cross-section of stripline Tx line using Transmission Line Toolkit
- Defining the solution setup
- Analyzing the model
- Exporting a *W*-element model.

## • 2D Extractor Overview

- The ANSYS 2D Extractor is an electromagnetic field solver that extracts transmission line parameters from the two-dimensional cross-section of an arbitrary multi-conductor transmission line. Two separate field solvers are applied to extract the parameters necessary to create the transmission line model.
  - **Electrostatic Solver:** Given the voltage applied on the conductors, the electrostatic solver calculates charge on all conductors. The capacitance and conductance per unit length are derived from the electrostatic field solution.
  - **Magnetostatic Solver:** Given the current injected into a conductor, the magnetostatic solver calculates the magnetic flux intersecting all conductors. The inductance and resistance per unit length are derived from the magnetostatic field solution.
- Most transmission lines used for high speed signaling are comprised of two or more parallel conductors. If the conductors are close together, the transmission lines can be characterized in terms of frequency dependent R (resistance), L (inductance), C (capacitance), G (conductance) matrices. This condition must be satisfied in order for the solution from the 2D extractor to be valid.
- A widely used model for transmission lines is the *W*-element model, which is a table listing the frequency dependence of these RLCG parameters.

Here is a cascaded RLCG model approximating a two conductor transmission line. RLCG generally depend on frequency.

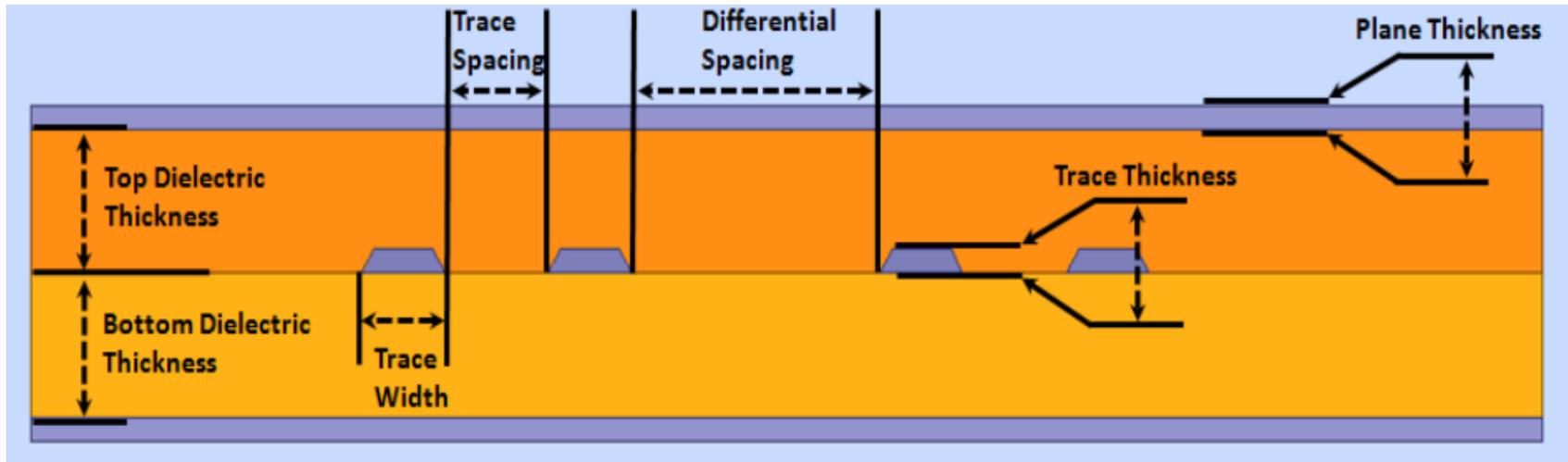


## • Transmission Line Toolkit

- We will be using the Toolkit to create the 2D geometry and setting up the simulation parameter for the 2D Parameter extractor to solve. The toolkit can also be used to get quick  $Z_0$  and  $Z_{diff}$  parameters analytically.

## • Differential Stripline

- This example demonstrates how to set up and analyze a differential stripline transmission line as shown below.
- This example will also teach you how to export a frequency-dependent tabular W-element for use with a transient circuit simulator.



**Plane Thickness = 2mils, Trace Thickness = 2mil, Trace Width = 5mil  
Trace Spacing = 5mil, Bottom Dielectric = 7 mil, Top Dielectric = 7mils  
Differential Spacing = 15mil**

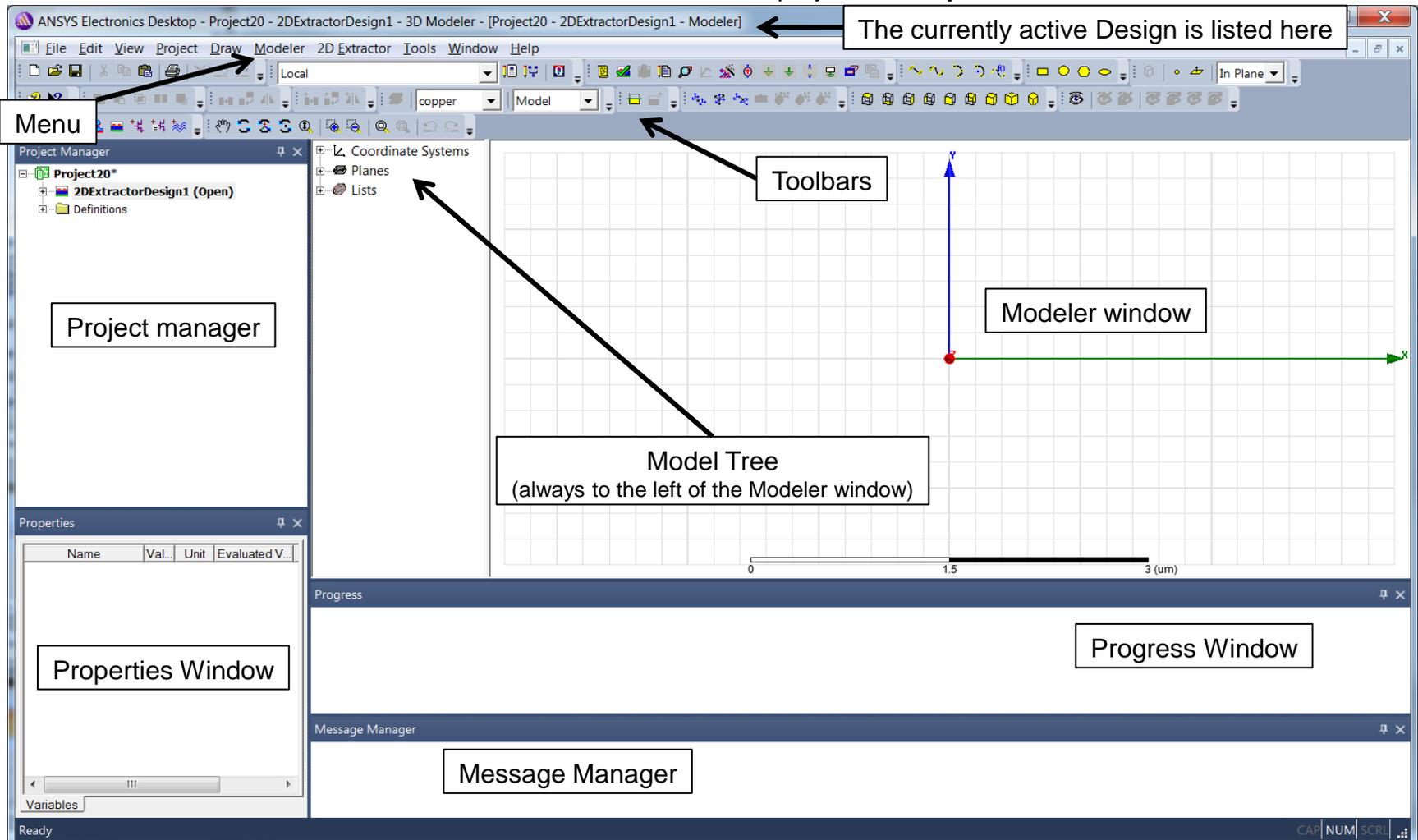
- **Launch Q3D Extractor**

- The 2D Extractor is part of the product Q3D Extractor (or Q3D), which encompasses both a three-dimensional and a two-dimensional quasi-static field solver. The following exercise focuses entirely on the 2D Extractor portion of the Q3D and the Transmission Line Toolkit.
- Launching Q3D: To access the Q3D Extractor, click the Microsoft Start button and select ***All Programs > ANSYS Electromagnetics > ANSYS Electromagnetics Suite 16.2 > ANSYS Electronics Desktop 2015.2***

# 2D Extractor User Interface

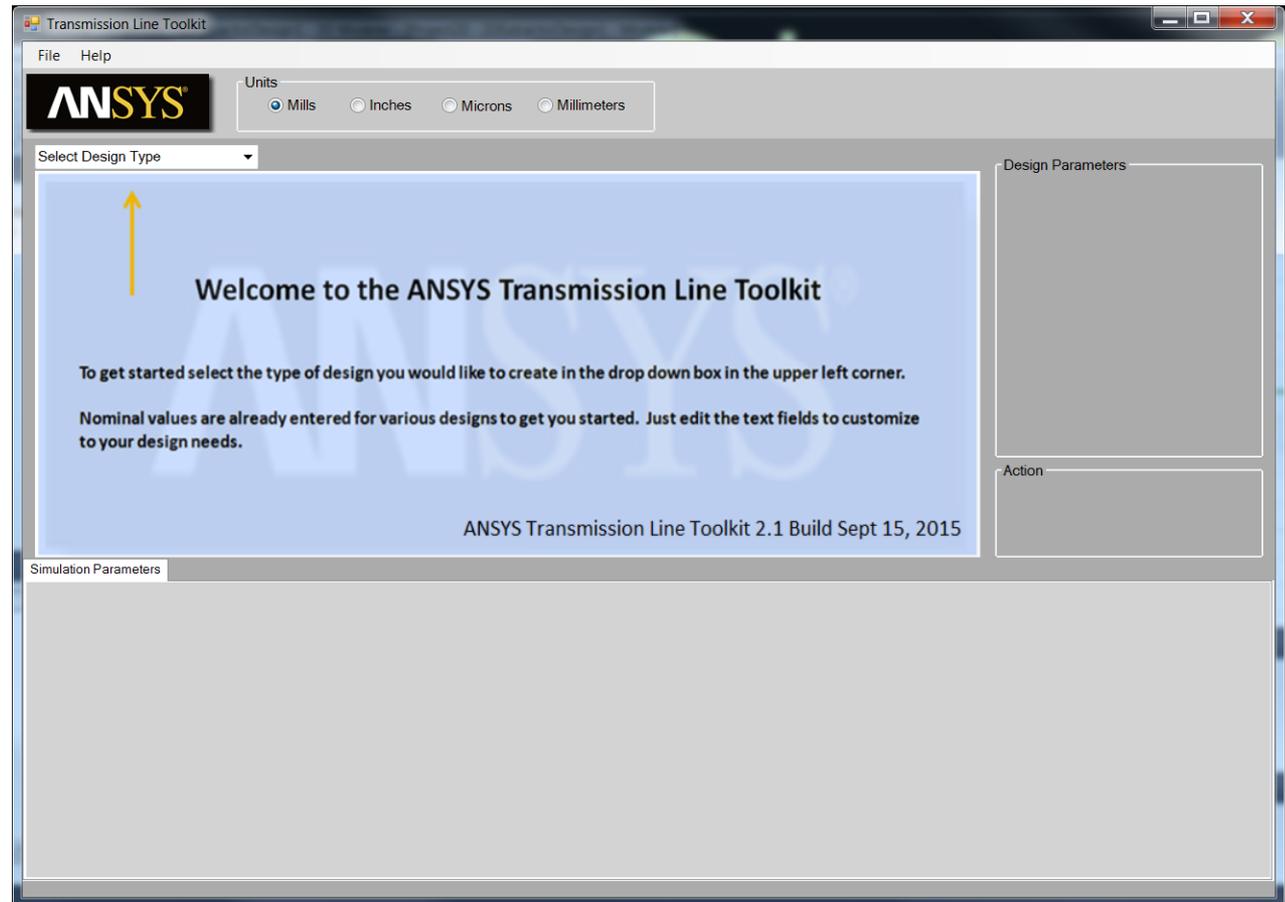
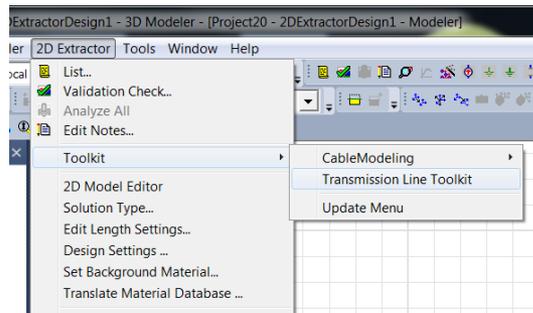
- **Insert a 2D Extractor Design**

- From the menu select **Project > Insert 2D Extractor Design**. A 2-D modeling window will appear as shown below.
- Save the file. From the menu select **File > Save**. Name the project **diffstrip**



- **Launch Transmission Line Toolkit**

- From the Menu select **2D Extractor > Toolkit > Transmission line Toolkit** A Transmission Line Toolkit modeling window will appear.



# Transmission Line Toolkit

## • Setup Transmission Line Parameter and Simulation Parameters

- Select Stripline – Differential Line Type from the drop down menu
- Make sure the units are in Mils which is default

**Units**

Stripline - Differential

Design Parameters	
Number of Traces	4
Plane Thickness	0.85 mil
Trace Thickness	0.85 mil
Trace Width	4 mil
Trace Spacing	10 mil
Bottom Dielectric	6 mil
Top Dielectric	6 mil
Differential Spacing	16 mil

**Simulation Parameters**

**Solution Setup**  
 Solution Frequency: 10 GHz  
 Frequency Sweep:  None  Discrete  Interpolating

**Advanced Conductor Options**  
 Surface Roughness Modeling:  None  Hammerstad-Jensen  Huray  
 Trace Etching:

**Dielectric Properties**  
 Fill in material characteristics, example values preloaded. Values will automatically be fit with Djordjevic-Sarker Model

	Top Dielectric	Bottom Dielectric
Frequency:	1 GHz	1 GHz
Relative Permittivity:	4	4
Loss Tangent:	0.02	0.02

## • Setup Transmission Line Parameter

- Use the Transmission Line Design Parameters shown in the window below. These were explained in slide #3
- Click Calculate to get Z0 value

Transmission Line Toolkit

File Help

ANSYS

Units:  Mills  Inches  Microns  Millimeters

Stripline - Differential

Geometry

Design Parameters

Number of Traces	4
Plane Thickness	2 mil
Trace Thickness	2 mil
Trace Width	5 mil
Trace Spacing	5 mil
Bottom Dielectric	7 mil
Top Dielectric	7 mil
Differential Spacing	15 mil

Action

Calculate Z0: 43.86

Create Z0diff: 76.92

Simulation Parameters

Solution Setup

Solution Frequency: 10 GHz

Frequency Sweep:  None  Discrete  Interpolating

Advanced Conductor Options

Surface Roughness Modeling: Trace Etching

None  Hammerstad-Jensen  Huray

Dielectric Properties

Fill in material characteristics, example values preloaded. Values will automatically be fit with Djordjevic-Sarker Model

Top Dielectric	Bottom Dielectric
Frequency: 1 GHz	Frequency: 1 GHz
Relative Permittivity: 4	Relative Permittivity: 4
Loss Tangent: 0.02	Loss Tangent: 0.02

# Transmission Line Toolkit

- Setup Advanced Conductor Options: Surface Roughness
  - Select Huray surface roughness model with the default values

**Design Parameters**

Number of Traces	4
Plane Thickness	2 mil
Trace Thickness	2 mil
Trace Width	5 mil
Trace Spacing	5 mil
Bottom Dielectric	7 mil
Top Dielectric	7 mil
Differential Spacing	15 mil

**Simulation Parameters**

Solution Setup  
 Solution Frequency: 10 GHz  
 Frequency Sweep:  None  Discrete  Interpolating

**Advanced Conductor Options**

Surface Roughness Modeling:  None  Hammerstad-Jensen  Huray

Top of Trace:  
 Hall-Huray Surface Ratio: 2.5  
 Nodule Radius: 0.5

Sides of Trace:  
 Hall-Huray Surface Ratio: 2.5  
 Nodule Radius: 0.5

Bottom of Trace:  
 Hall-Huray Surface Ratio: 2.5  
 Nodule Radius: 0.5

Units: um

Example Values Pre-Loaded

**Dielectric Properties**

Fill in material characteristics, example values preloaded. Values will automatically be fit with Djordjevic-Sarker Model

Frequency:	1 GHz	1 GHz
Relative Permittivity:	4	4
Loss Tangent:	0.02	0.02

# Transmission Line Tool Kit

- Setup Advanced Conductor Options: Trace Etching

- Click on the Trace Etching tab and add Over Etch factor ~5 using the slider

Transmission Line Toolkit

File Help

ANSYS

Units  
 Mills  Inches  Microns  Millimeters

Stripline - Differential

Trace Spacing Differential Spacing Plane Thickness  
 Top Dielectric Thickness Bottom Dielectric Thickness Trace Width Trace Thickness

Design Parameters

Number of Traces	4
Plane Thickness	2 mil
Trace Thickness	2 mil
Trace Width	5 mil
Trace Spacing	5 mil
Bottom Dielectric	7 mil
Top Dielectric	7 mil
Differential Spacing	15 mil

Action

Calculate Zo: 43.86  
 Create Zoddiff: 76.92

Simulation Parameters

Solution Setup  
 Solution Frequency 10 GHz  
 Frequency Sweep  
 None  Discrete  Interpolating

Advanced Conductor Options

Surface Roughness Modeling Trace Etching  
 None  Over Etch  Under Etch

Etch Factor: 5.03 Etching %, short to long: 15.9

Dielectric Properties

Fill in material characteristics, example values preloaded.  
 Values will automatically be fit with Djordjevic-Sarker Model

Frequency:	1 GHz	Bottom Dielectric	1 GHz
Relative Permittivity:	4	Relative Permittivity:	4
Loss Tangent:	0.02	Loss Tangent:	0.02

**Advanced Conductor Options**

# Transmission Line Toolkit

- **Setup Dielectric Material**

- For this exercise, use permittivity of 4.0 and loss tangent of 0.02 at 1 GHz for both the top and bottom dielectric.

The screenshot shows the ANSYS Transmission Line Toolkit interface. The main window displays a cross-section of a stripline differential pair with various parameters labeled: Trace Spacing, Differential Spacing, Plane Thickness, Top Dielectric Thickness, Bottom Dielectric Thickness, Trace Width, and Trace Thickness.

**Design Parameters:**

Number of Traces	4
Plane Thickness	2 mil
Trace Thickness	2 mil
Trace Width	5 mil
Trace Spacing	5 mil
Bottom Dielectric	7 mil
Top Dielectric	7 mil
Differential Spacing	15 mil

**Action:**

Calculate Zo: 43.86  
Create Zo: 76.92

**Simulation Parameters:**

Solution Setup: Solution Frequency 10 GHz, Frequency Sweep: None (selected), Discrete, Interpolating.

**Advanced Conductor Options:**

Surface Roughness Modeling: None (selected), Over Etch, Under Etch. Etch Factor: 5.03, Etching %, short to long: 15.9.

**Material Properties (highlighted in red):**

Dielectric Properties: Fill in material characteristics, example values preloaded. Values will automatically be fit with Djordjevic-Sarker Model.

	Top Dielectric	Bottom Dielectric
Frequency:	1 GHz	1 GHz
Relative Permittivity:	4	4
Loss Tangent:	0.02	0.02

# Transmission Line Toolkit

## • Setup Simulation Parameters

- Select Solution Frequency of 10 GHz
- Also select Interpolating sweep from 0 – 10 GHz with a step of 100MHz

The screenshot shows the ANSYS Transmission Line Toolkit interface. The main window displays a cross-section of a stripline differential pair with various parameters labeled: Trace Spacing, Differential Spacing, Plane Thickness, Top Dielectric Thickness, Bottom Dielectric Thickness, Trace Width, and Trace Thickness.

**Design Parameters:**

Number of Traces	4
Plane Thickness	2 mil
Trace Thickness	2 mil
Trace Width	5 mil
Trace Spacing	5 mil
Bottom Dielectric	7 mil
Top Dielectric	7 mil
Differential Spacing	15 mil

**Action:**

Calculate Zo: 43.86  
Create Zodiff: 78.92

**Solution Parameters:**

**Solution Setup:**

- Solution Frequency: 10 GHz
- Frequency Sweep:  Interpolating
- Frequency Start: 0 GHz
- Frequency Stop: 10 GHz
- Frequency Step: 100 MHz

**Advanced Conductor Options:**

Surface Roughness Modeling:  Over Etch

Etch Factor: 5.03 Etching %, short to long: 15.9

**Dielectric Properties:**

Fill in material characteristics, example values preloaded. Values will automatically be fit with Djordjevic-Sarker Model

	Top Dielectric	Bottom Dielectric
Frequency:	1 GHz	1 GHz
Relative Permittivity:	4	4
Loss Tangent:	0.02	0.02

# Transmission Line Tool Kit

- Calculate Analytical Zo and Zdiff and Create geometry

- Zo and Zdiff is calculated using analytically using equation specified by IPC-D-317A
- Click on **Create** to create the geometry to be solved using 2D Field Solver. This creates a new project in the project manager

Transmission Line Toolkit

File Help

ANSYS

Units:  Mills  Inches  Microns  Millimeters

Stripline - Differential

Trace Spacing

Differential Spacing

Plane Thickness

Top Dielectric Thickness

Bottom Dielectric Thickness

Trace Width

Trace Thickness

Design Parameters

Number of Traces	4
Plane Thickness	2 mil
Trace Thickness	2 mil
Trace Width	5 mil
Trace Spacing	5 mil
Bottom Dielectric	7 mil
Top Dielectric	7 mil
Differential Spacing	15 mil

**Zo/Zdiff and Create**

Action

Calculate Zo: 43.86

Create Zdiff: 76.92

Simulation Parameters

Solution Setup

Solution Frequency: 10 GHz

Frequency Sweep:  None  Discrete  Interpolating

Frequency Start: 0 GHz

Frequency Stop: 10 GHz

Frequency Step: 100 MHz

Advanced Conductor Options

Surface Roughness Modeling:  None  Over Etch  Under Etch

Etch Factor: 5.03 Etching %, short to long: 15.9

Dielectric Properties

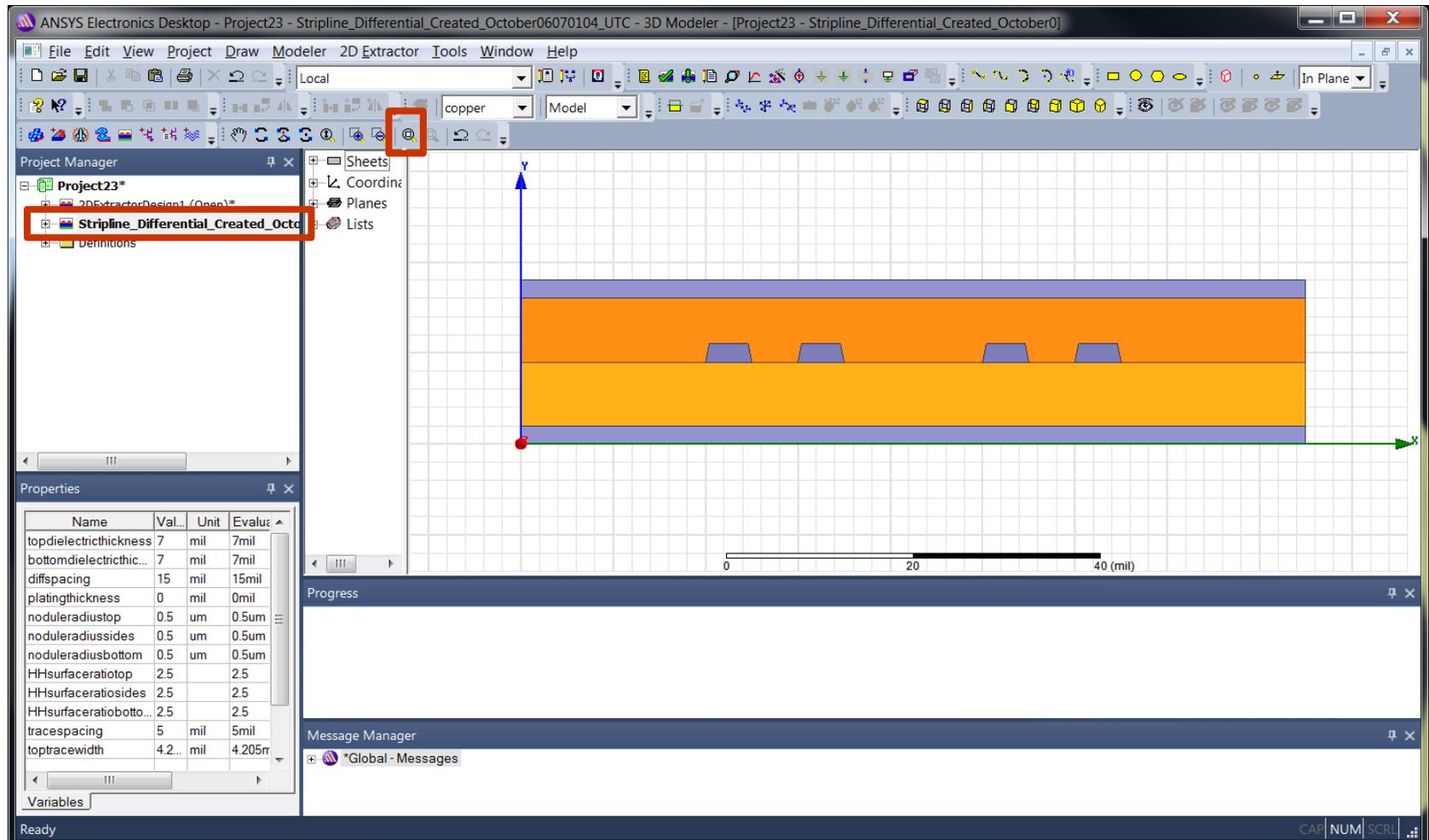
Fill in material characteristics, example values preloaded. Values will automatically be fit with Djordjevic-Sarker Model

	Top Dielectric	Bottom Dielectric
Frequency:	1 GHz	1 GHz
Relative Permittivity:	4	4
Loss Tangent:	0.02	0.02

# 2D Parameter Extractor

- Exit out of Toolkit by clicking on File > Exit

- You see the window below after you exit. A new project is created in the project manager window. You may need to do CTRL-D/FIT ALL to see the transmission line model





# Results

## • Solution Data

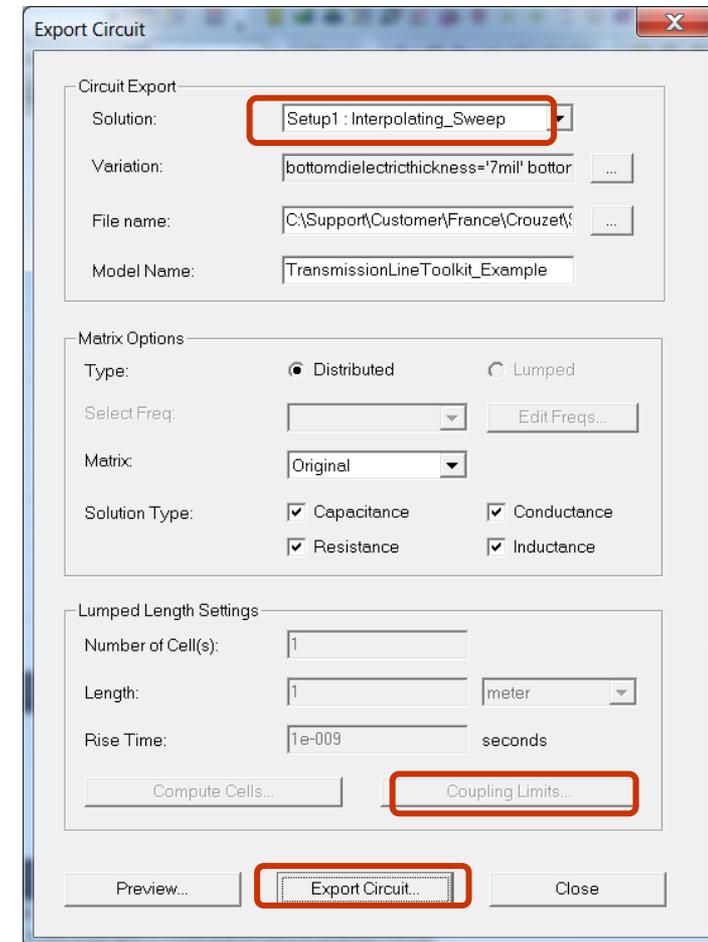
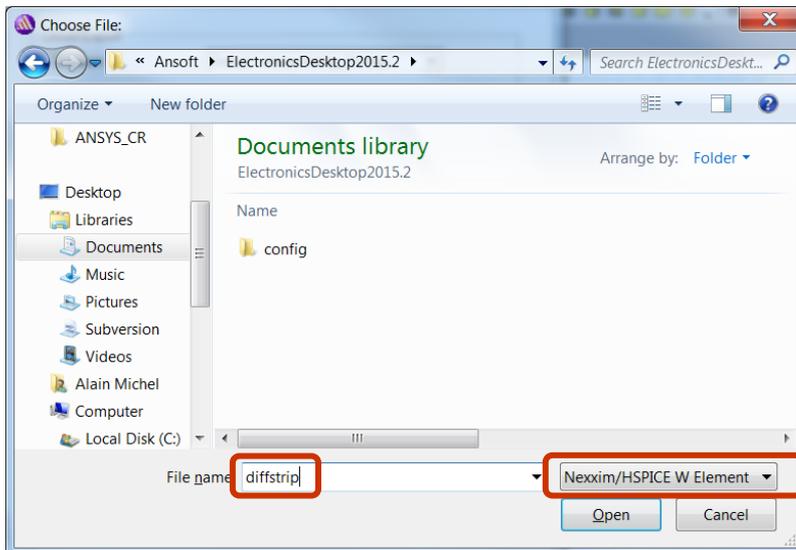
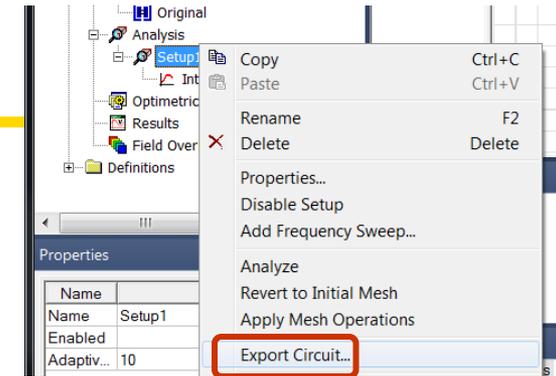
- Select the menu item **2D Extractor > Results > Solution Data**
  - To view the RLGC Matrix Data, Click the **Matrix** Tab
  - To view **CG** matrix, select **CG** from the drop down list
  - You can view the **RL** matrix selecting **RL** from the drop down list

The screenshot shows the 'Solutions: TransmissionLineToolkit\_Example - Stripline\_Differential\_Created\_October06070104\_UTC' dialog box. The 'Simulation' dropdown is set to 'Setup1' and 'Interpolating\_Sweep'. The 'Matrix' dropdown is set to 'CG'. The 'Design Variation' field contains: 'ss='0mil' topdielectricthickness='7mil' totracewidth='4.205mil' tracespacing='5mil' tracethickness='2mil''. The 'Matrix' tab is selected, and the 'Conductance' and 'Capacitance' checkboxes are checked. The 'Passivity Tolerance' is set to '0.0001'. The table below shows the matrix data for 'Freq: 0 (GHz)'. The 'Close' button is at the bottom.

	Trace1 (mSie/meter, pF/meter)	Trace2	Trace3	Trace4
Trace1	4.2486E-009, 168.87	-6.6047E-010, -26.251	-5.4689E-013, -0.021736	-4.8487E-015, -0.00019541
Trace2	-6.6047E-010, -26.251	4.2498E-009, 168.91	-6.5226E-011, -2.5925	-5.4694E-013, -0.021738
Trace3	-5.4689E-013, -0.021736	-6.5226E-011, -2.5925	4.2496E-009, 168.9	-6.6009E-010, -26.236
Trace4	-4.8487E-015, -0.00019541	-5.4694E-013, -0.021738	-6.6009E-010, -26.236	4.2484E-009, 168.86

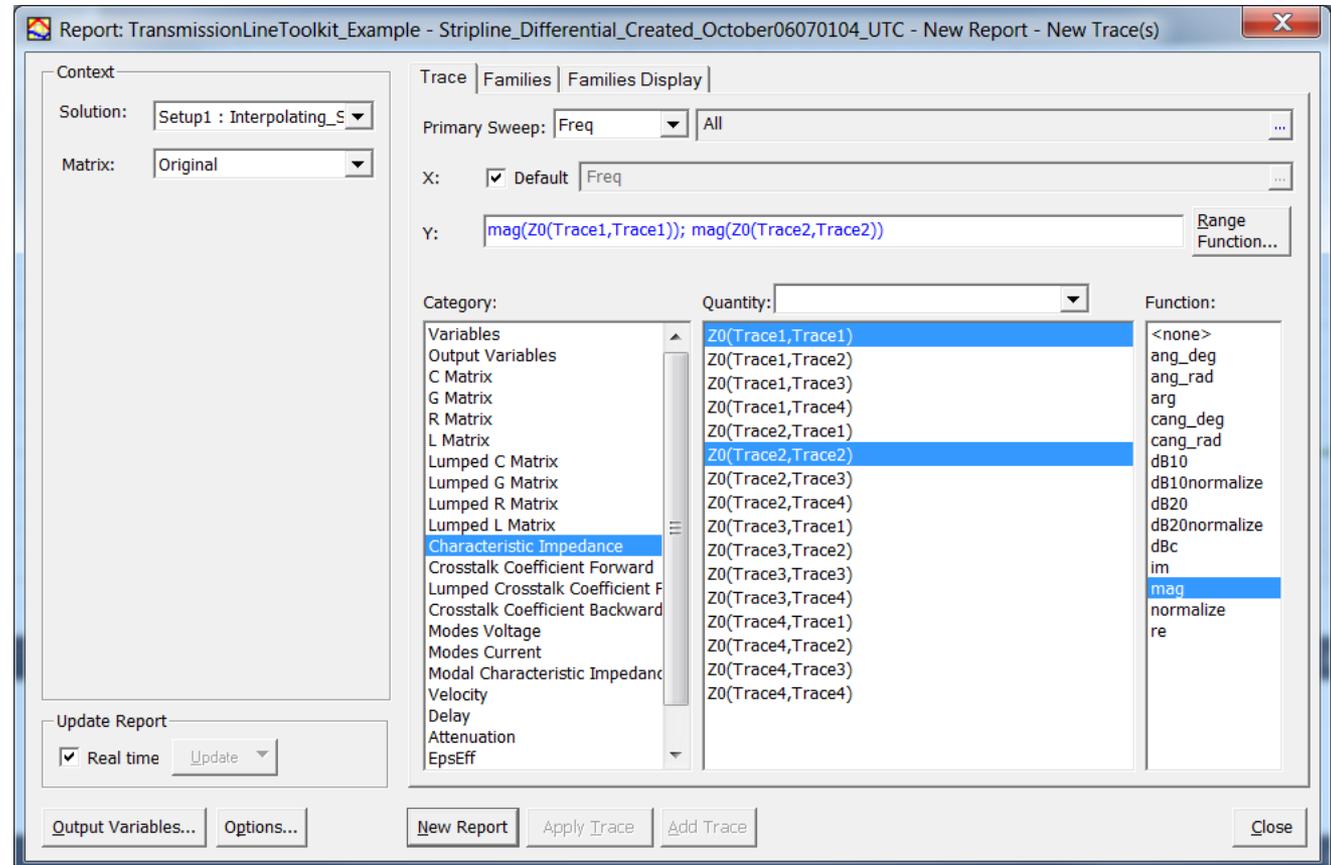
## • Export the W-Element Model

- Click with the right mouse button on the **Setup1** in the **Project Manager**. Choose the option **Export Circuit...**
- Be sure to select **Setup1 : Interpolating\_sweep** for the solution so that frequency dependence is included in the model.
- Press the **...** next to **File name** and browse to the location where the model should be saved.
- Select **Nexxim/HSPICE W Element** as the file type.
- Use file name **diffstrip** and Press **Open**.
- Press **Export Circuit...** to write the model to the file.
- Press the **OK** button on the window indicating the file is **diffstrip.sp** to exit.
- Click **Close** to exit the Export Circuit window.

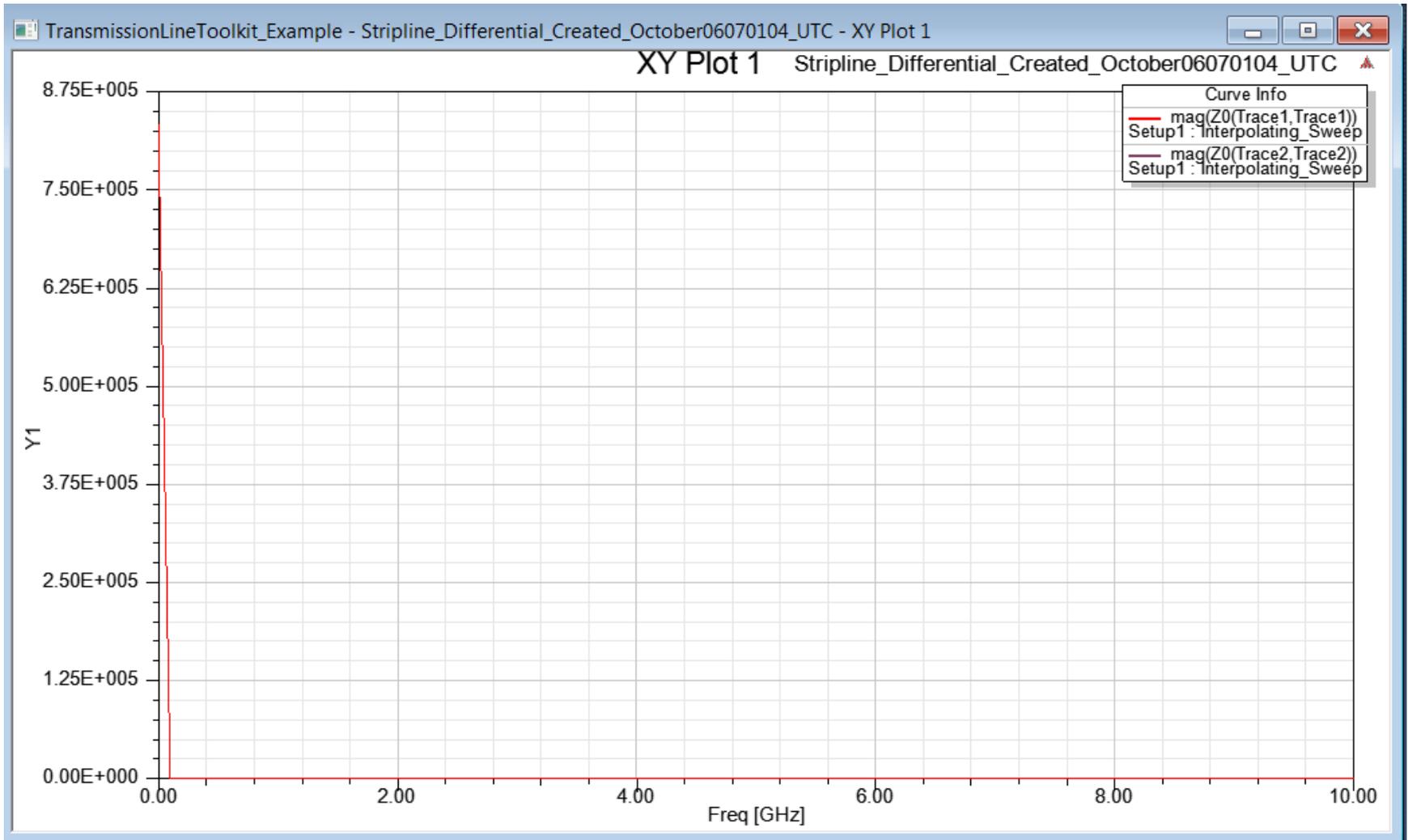


## • Plot Characteristic Impedance

- Select the menu item **2D Extractor > Results > Create Matrix Report > Rectangular Plot**.
- From the Create Report dialog box
  - Category: **Characteristic Impedance**
  - Quantity: **Z0(trace1, trace1), Z0(trace2, trace2)**
  - Function: **mag**
  - Press **New Report**
  - Press **Close**



- This is the plot you see with default setting



- Double click anywhere in the plot area select tab **X Scaling**. Specify **Min** as 0.01 and **Max** as 10, **Spacing** of 5 and **Minor Ticks** as 5
- Select Tab **Y1 Scaling**. Specify **Min** of 0 and **Max** of 80 and spacing of 10 and Minor Ticks of 2. The Zo plot should look like the one on the next slide now.

