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ECE 451: Ansys HFSS Tutorial Simulate and Analyze an Example of Microstrip Line

Drew Handler, Jerry Yang October 20, 2014







Introduction

- ANSYS HFSS is an industry standard tool for simulating 3-D full-wave electromagnetic fields.
- Students registered in ECE451 can get free access to ANSYS HF package from the University of Illinois Software Webstore.
- Follow the installation guide* to install the software on your PC.

*Note: You will need to e-mail your computer name and a copy of the purchase receipt to <u>webstore@illinois.edu</u>. Allow 1-2 business days for your computer to be added to the license pool.





Launch HFSS:

- Start→All Programs→ANSYS
 Electromagnetics→HFSS
 15.0→Windows 64-bit (or 32-bit)→HFSS 15.0
- Set HFSS options:
 - Tools→Options→HFSS
 Options→General Tab
 - Check ✓Use Wizards for data input when creating new boundaries
 - Check ✓ Duplicate boundaries/mesh operations with geometry
 - Click OK

FSS Options	×
General Solver	
Solution Type Options	
Default solution type: DrivenModal	
Material Options	
Include ferrite materials.	
Solve Inside threshold: 100000 Siemens/m	
Assignment Options	
Use Wizards for data input when creating new boundaries.	
Duplicate boundaries/mesh operations with geometry.	
Visualize boundaries on geometry.	
Auto-assign terminals on ports.	
Post Processing Options	
Default matrix sort order: Ascending alphanumeric	
Save before solving.	
Save Optimetrics field solutions.	
Apply variation deletions immediately.	
OK Cancel	

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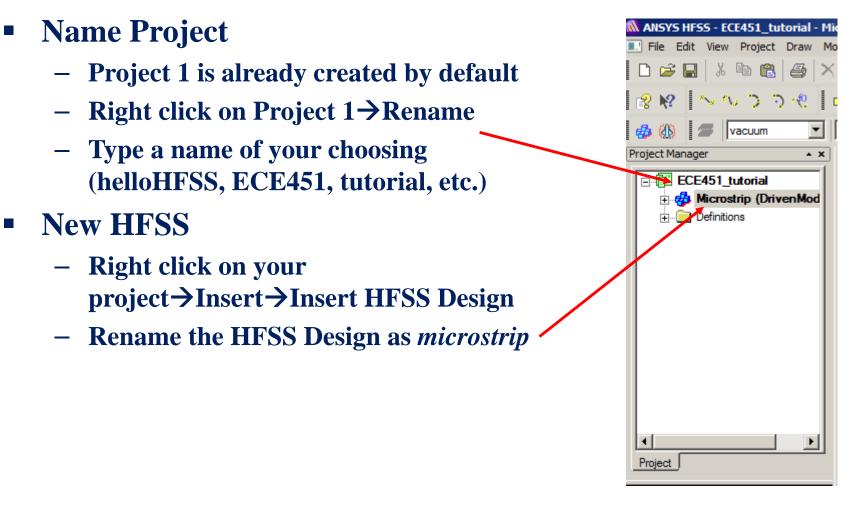
- Set Modeler options:
 - Tools→Options
 →Modeler Options
 - Operation Tab
 - Check

 ✓ Automatically
 cover closed
 polylines
 - Check ✓ Select last command on object select
 - Drawing Tab
 - Check ✓ Edit properties of new primitives
 - Click OK

Modeler Options	×	Modeler Options	×
Operation Display Drawing		Operation Display Drawing	
		· · · · · · · · · · · · · · · · · · ·	×
 Desktop computes the geometry Desktop computation for models with CAD integration (dynamic links) and geometry sharing in ANSYS Workbench is always by Desktop. 			
OK Cance		OK Cancel	











- Set the solution type:
 - − Click on HFSS→Solution Type
 - Select Modal
 - Click OK
- Set Model Unit:
 - − Click on Modeler→Units
 - Select mil from the drop down menu
 - Click OK

Solution Type: ECE451_tutorial - Microstrip						
Driven Modal Terminal Transient	 Network Analysis 					
C Eigenmode						
OK	Cancel					

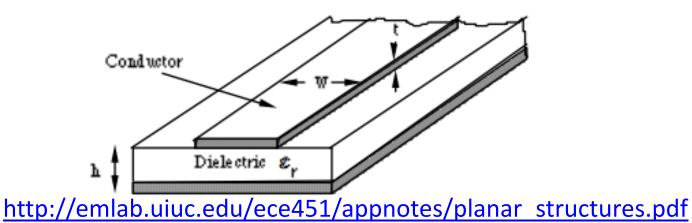
Set Model Units	×
Select units: mil	
Rescale to new units	
OK Cancel	





Creating the Microstrip

We are going to make the substrate (a.k.a dielectric layer), ground plane, and copper trace (conductor) for a microstrip line.



To do this, we will make three "boxes" in HFSS, and then designate the appropriate dimensions and material for each box.





Creating the Microstrip

First we are going to define several variables for the dimensions of our substrate, ground plane, and copper trace

- Select HFSS→Design Properties→Add

- Fill in the properties as shown below

Add Property	tanan Chen	7 Sec.	C Same	×
Name microstrip_L	 Variable ArrayIndexV 	C Separator 'ariable	C PostProcessingVariable	•
Unit Type Length	✓ Units mil		•	
Value 1000				
Enter a number with 2*cos(\$x).	units, variable, or expression into the Value f	ield. Referenced project varial	bles should be prefixed with a '\$'. Exampl	es: 22.4pF, \$C1,
			OK	Cancel
– Click	OK			

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Creating the Microstrip

Repeat the previous steps to create 7 more variables with the following values:

- Substrate_W 1000 mil
- Substrate_H 60 mil
- Gnd_H 4 mil
- Trace_W 114.7mil
- Trace_H 4 mil
- Waveport_W 419 mil
- Waveport_H 115 mil

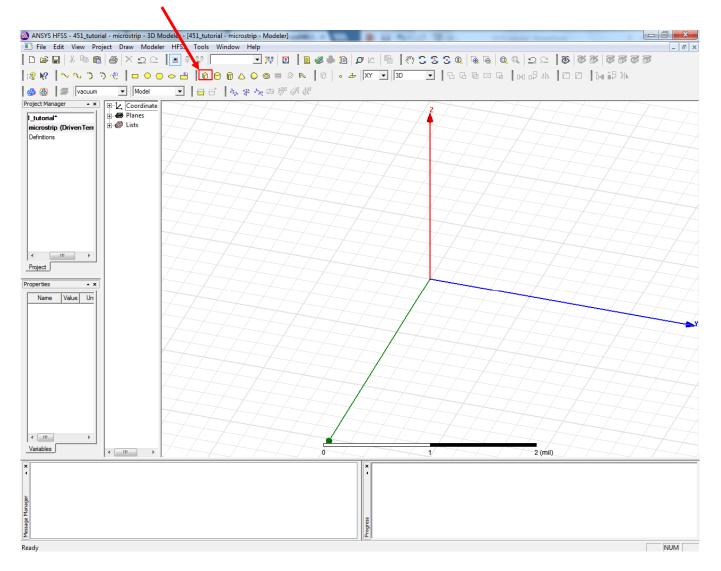
Using these variables, we will define a 1.00"x1.00" board with a 60 mil thick substrate, 4 mil thick ground plane and trace, and 107.4 mil wide trace

**<u>Recall</u>: 1 inch =1000 mil = 25.4mm



Creating the Microstrip (1): Substrate

Select the Draw Box button







Creating the Microstrip (1): Substrate

- Once you have selected the draw box, move your cursor into the window the 3D axis shown
 - Click anywhere, move your mouse in the XY plane, click again, move your mouse in the Z direction, and click a third time
- You have now created an arbitrary sized box
- A window will pop up in which you can define the dimensions and location of the box
 - Fill in the location and dimension as shown below





Creating the Microstrip (1): Substrate

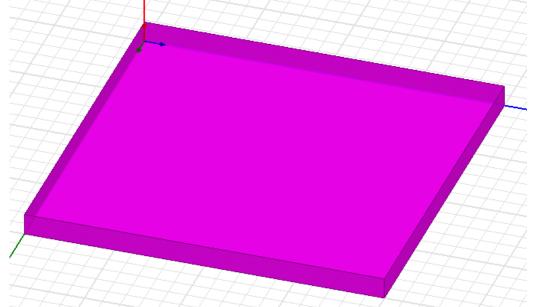
Propertie	es: 451_tutorial - m	nicrostrip - Modeler				×
Comma	and Attribute					
Γ	Name	Value	Unit	Evaluated Value	Description	
	Command	CreateBox				
	Coordinate Sys	Global				
	Position	0, 0, 0	mil	Omil , Omil , Omil		
	XSize	substrate_W		1000mil		
	YSize	microstrip_L		1000mil		
	ZSize	substrate_h		60mil		
					Show Hidden	
					ОК	Cancel

- Click OK
- You may need to zoom out in order to see your box (scroll down with your mouse to zoom out)

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Creating the Microstrip (1): Substrate You should have a box that looks like this



- To change your view in 2D, hold <u>Shift + left click and drag</u>
- To change your view in 3D, hold <u>Alt + left click and drag</u>
- To fit the view in the 3D modeler window: <u>Ctrl+D</u>





Creating the Microstrip (1): Substrate This box now has the dimensions that we want for our substrate. The next step is to define the material of our substrate.

- Double click on "Box1" and fill in the properties as
 - shown below
- Details on
 - next slide

Coordir Planes						
Lists Propert	ties: 451_tutorial - r	microstrip - Modeler				
Attrib	ute					
	Name	Value	Unit	Evaluated Value	Description	Read-only
	Name	substrate				
	Material	"FR4_epoxy"		"FR4_epoxy"		
	Solve Inside	~				
	Orientation	Global				
	Model	✓				
	Display Wirefra.					
	Color					
	Transparent	0.8				
					□ SH	now Hidden





Creating the Microstrip (1): Substrate

- Change the name from Box1 to substrate
- Change the material from vacuum to FR4_epoxy
 - Select Edit from the material drop down menu
 - In the Search by Name box, type in fr
 - FR4_epoxy should be highlighted
 - Click OK
- Change the color to whatever you want
- Change the transparency to 0.8





Creating the Microstrip (2): Gnd Plane Now we are going to make the ground plane – Draw another arbitrary sized box and fill in the location and dimension as shown below

Propertie	s: 451_tutorial - m	nicrostrip - Modeler				X
Commar	Attribute					
	Name	Value	Unit	Evaluated Value	Description	
	Command	CreateBox				
	Coordinate Sys	Global				
	Position	0.0.0	mil	Omil , Omil , Omil		
	XSize	substrate_W		1000mil		
	YSize	microstrip_L		1000mil		
	ZSize	-gnd_H		-4mil		
					Show Hidden	
					OK Cance	el

- Make sure the ground height is negative

• Alternatively, you could make the position 0,0,-gnd_H and keep the ZSize positive



Creating the Microstrip (2): Gnd Plane Now we have our ground plane with the correct dimensions and location, but still need to change the material.

- Double click on Box1
- Change the name to gnd_plane
- Change the material to copper
- Change the color
- Make the transparency 0.8



Creating the Microstrip (3): Trace

The last part of building our microstrip line is to add the microstrip trace. To do this, create another box and fill in the location and dimensions as shown below.

NameValueUnitEvaluated ValueDescriptionCommandCreateBoxIIIIIICoordinate SysGlobalIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	i ivame	Value	Unit	Evaluated Value	Description
Coordinate Sys Global 442.65mil , 0 , 6 Position substrate_W/2trace_W/2,0 ,substrate_H 442.65mil , 0 , 6 XSize trace_W 114.7mil YSize microstrip L 1000mil			Unit	Evaluated value	Description
Position substrate_W/2+race_W/2 ,0 ,substrate_H 442.65mil , 0 , 6 XSize trace_W 114.7mil YSize microstrip L 1000mil					
XSize trace_W 114.7mil YSize microstrip_L 1000mil					
YSize microstrip L 1000mil	Position	substrate_W/2trace_W/2 ,0 ,substrate_H		442.65mil , 0 , 6	
	XSize	trace_W		114.7mil	
ZSize trace H 4mil	YSize	microstrip_L		1000mil	
	ZSize	trace H		4mil	





Creating the Microstrip (3): Trace

Again we need to change the material

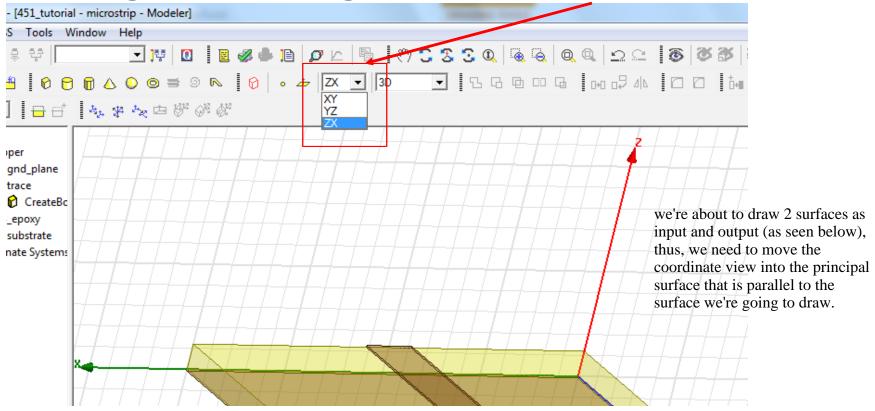
- Double click on Box1
- Change the name to trace
- Change the material to copper
- Change the color
- Make the transparency 0.8





Our model for our microstrip line is almost complete and ready to simulate. We still need to define the excitation for our model.

• Change the Drawing Plane from XY to ZX







- Draw a rectangle (not a box)
- Double click on create rectangle and fill in the position and dimensions as shown below

FR4_epoxy 	Properties: 45	1_tutorial - m	icrostrip - Modeler						×
⊡ CreateRectangle ⊡ CoverLines ⊡, Coordinate Systems	Command	Name		Value		Unit	Evaluated Value	Description	
🕀 🖉 Planes			C . B	value		Unit	Evaluated value	Description	
			CreateRectangle						_
		oordinate Sys osition		+ W/O estavoltion I and			200 5-1 1000		_
			SUDStrate_VV/2-wavepo	rt_W/2 ,microstrip_L ,-gnd	_H		290.5mil , 1000		_
							419mil		_
			waveport_W				4 i 9mii 115mil		_
		Size	waveport_H				IIImci I		
								Show Hidden	
								ОК	Cancel





- Draw a second rectangle
- Double click on create rectangle and fill in the position and dimensions as shown below

CreateRectangle	ties: 451_tutorial - m mand	icrostrip - Modeler				
Global	Name	Value	Unit	Evaluated Value	Description	
🕀 🖅 🖅 Planes	Command	CreateRectangle				
⊕ - 🥔 Lists	Coordinate Sys	Global				
	Position	Position substrate_W/2-waveport_W/2 ,0mil ,-gnd_H 290.5mil , 0mil ,				
	Axis	Y				
	XSize	waveport_W		419mil		
	ZSize	waveport_H		115mil		
					Show Hidden	
					OK Cancel	

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- Right click rectangle $2 \rightarrow Assign Excitation \rightarrow Wave Port$

- Wave Port: General leave the port number 1 and click Next
- Wave Port: Modes leave default settings and click Next
- Wave Port: Post Processing select Renormalize All Modes and leave the Full Port Impedance as 50 Ohms
- **Click Finish**

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if we dont this step, we still have another chance to do it when export the data to touchstone file. There will be an option says "Override Solution Renormalization" with the option 500hms as default.

Wave Port : General	X Wave Port : Modes X	Wave Port : Post Processing
Pame: 2 rectangles are input and output, we need to assign excitation on them both before run the simulation. it's like in ADS, we have to use termination attach to 2 ports in homework 4	Number of Modes: Mode Integration Line Characteristic Impedance (Zo) 1 None Zpi	Port Renormalization Do Not Renormalize Renormalize All Modes Full Port Impedance: 50 ohm Renormalize Specific Modes Edit Mode Impedances Described Settings
in the coax_T example of HFSS workshop, we assign the wave port first then duplicate the cylinder to form the T shape later, thus other 2 ports of the T shape already have the wave port assigned.	Mode Alignment and Polarity:	

Repeat the steps above to make rectangle 1 Wave Port 2





Creating the Air Box

HFSS treats the space around your design that hasn't been designated as a specific material as PEC. Because of this, we need to define an airbox around our design.

- Change the Drawing Plane back from ZX to XY
- Draw a box and fill in the values as shown below

Properti	es: 451_tutorial - m	nicrostrip - Modeler					X
Comm	and						
Г	Name	Va	alue	Unit	Evaluated Value	Description	
	Command	CreateBox					
ľ	Coordinate Sys	Global					
	Position	-substrate W/2 ,0mil ,-gnd H			-500mil , 0mil ,		
Ĩ	XSize	2*substrate_W			2000mil		
	YSize	microstrip_L			1000mil		
	ZSize	10*substrate_H			600mil		
						Show Hidden	
						ОК	Cancel





Creating the Air Box

- Double click on Box1
 - Rename it as airbox
 - Change the material to air
 - Change the color
 - Make the transparency 0.8





Add Solution Setup

Click on HFSS→Analysis Setup→Add Solution Setup

General Tab:

- Solution Frequency: 10 GHz
- Maximum Number of Passes: 20
- Maximum Delta S: 0.02

Options Tab:

- Minimum Converged Passes: 2
- Order of Basis Function: Zero Order

Click OK

neral Options Advanced Expression	Cache Derivatives Defaults
Initial Mesh Options	
Do Lambda Refinement	
Lambda Target: 0.1	Use Default Value
Use Free Space Lambda	
Adaptive Options Maximum Refinement Per Pass:	30 %
Maximum Refinement:	100000
_	1
Minimum Number of Passes:	2
Minimum Converged Passes:	2
Solution Options	
Order of Basis Functions:	Zero Order
Enable Iterative Solver	
Relative Residual:	0.0001
Enable Use of Solver Domains	,
Enable Use of Solver Domains	
Use Defau	ults
	OK Can
en Solution Setup neral Options Advanced Expression	
neral Options Advanced Expression Initial Mesh Options Do Lambda Refinement Lambda Target: 0.1	Cache Derivatives Defaults
neral Options Advanced Expression Initial Mesh Options ✓ Do Lambda Refinement Lambda Target: 0.1 ✓ Use Free Space Lambda	Cache Derivatives Defaults
neral Options Advanced Expression Initial Mesh Options D Lambda Refinement Lambda Target: 0.1 Use Free Space Lambda Adaptive Options	I Cache Derivatives Defaults
neral Options Advanced Expression Initial Mesh Options ✓ Do Lambda Refinement Lambda Target: 0.1 ✓ Use Free Space Lambda Adaptive Options Maximum Refinement Per Pass: ✓ Maximum Refinement:	Cache Derivatives Defaults
neral Options Advanced Expression Initial Mesh Options ✓ Do Lambda Refinement Lambda Target: 0.1	Cache Derivatives Defaults
Initial Mesh Options Advanced Expression Initial Mesh Options De Lambda Refinement Lambda Target: 0.1 Use Free Space Lambda Adaptive Options Maximum Refinement Per Pass: Minimum Number of Passes: Minimum Number of Passes:	Cache Derivatives Defaults Image: Cache Derivatives Default Image: Cache Default Value Image: Cache X Image: Cache Image: Cache X Image: Cache Image: Cache X Image: Cache
neral Options Advanced Expression Initial Mesh Options ✓ Do Lambda Refinement Lambda Target: 0.1	Cache Derivatives Defaults Image: Cache Derivatives Default Image: Cache Default Value Image: Cache X Image: Cache Image: Cache X Image: Cache Image: Cache X Image: Cache
Initial Mesh Options Advanced Expression Initial Mesh Options De Lambda Refinement Lambda Target: 0.1 Use Free Space Lambda Adaptive Options Maximum Refinement Per Pass: Minimum Number of Passes: Minimum Number of Passes:	Cache Derivatives Defaults Image: Cache Derivatives Default Image: Cache Default Value Image: Cache X Image: Cache Image: Cache X Image: Cache Image: Cache X Image: Cache
neral Options Advanced Expression Initial Mesh Options	I Cache Derivatives Defaults ↓ Use Default Value 30 % ↓ 000000 1 2
neral Options Advanced Expression Initial Mesh Options	I Cache Derivatives Defaults ↓ Use Default Value 30 % ↓ 000000 1 2
neral Options Advanced Expression Initial Mesh Options	Cache Derivatives Defaults
Initial Mesh Options Advanced Expression Initial Mesh Options	Cache Derivatives Defaults
neral Options Advanced Expression Initial Mesh Options D Lambda Refinement Lambda Target: 0.1 Use Free Space Lambda Adaptive Options Maximum Refinement Per Pass: Maximum Refinement: Minimum Number of Passes: Solution Options Order of Basis Functions: E Enable Iterative Solver Relative Residual:	Cache Derivatives Defaults
Initial Mesh Options Advanced Expression Initial Mesh Options	Cache Derivatives Defaults



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Add Frequency Sweep

Click on HFSS→Analysis Setup→Add Frequency Sweep

- Select Setup1 and click OK
- General tab:
 - Sweep Type: Interpolating
 - Frequency Setup
 - Type: Linear Step
 - Start: 300 kHz
 - Stop: 6 GHz
 - Step Size: 0.1 GHz
- Click OK

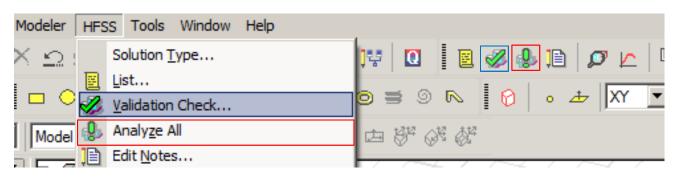
Sweep Name: Sweep Type:	Sweep Interpolating	•			I⊽ Er	nable
-Frequency Se				#	Frequency	Ŀ
Туре:	LinearStep	-		1	300kHz	
Start	300 kHz	ਚ	Display >>	2	100300kHz	
_		-		3	200300kHz	
Stop	6 GHz	-		4	300300kHz	
Step Size	0.1 GHz	•		5	400300kHz	
				6	500300kHz	
Time	e Domain Calculation			7	600300kHz	
				8	700300kHz	
				9	800300kHz	
				10	900300kHz	
				11	1000300kHz	
				12	1100300kHz	
				13	1200300kHz	



Validation Check and Analyze All Click on HFSS→Validation Check – If everything passes, close the validation check

window and you are ready to run your simulation

Validation Check: ECE451_tutorial - Microstrip	X
Validation Check completed.	 Design Settings 3D Model Boundaries and Excitations Mesh Operations Analysis Setup Optimetrics
Abort Close	 Radiation



- HFSS→Analyze All

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Plot S-Parameters

Click on HFSS→Results→Create Modal Solution Data Report→Rectangular Plot

- Select all 4 S-Parameters and click New Report

Report: 45	51_tutorial - microstrip - Nev	w Report - New Trace(s)
-Context		Trace Families Families Display
Solution:	Setup1 : Sweep 💌	Primary Sweep: Freq 🗸 All
Domain:	Sweep 💌	X: R Default Freq
	TDR Options	Y: dB(S(1,1)); dB(S(1,2)); dB(S(2,1)); dB(S(2,2)) Range Function
		Category: Quantity: Function: Variables S(1,1) <none></none>
		Output Variables S(1,2) ang_deg S Parameter S(2,1) ang_rad Y Parameter S(2,1) arg
-Update Rep	port	Z Parameter S(2,2) cang_deg cang_rad
Real tin	ne Update 🔻	Gamma +
Output Vari	ables Options	New Report Apply Trace Add Trace Close



Exporting S-Parameters

HFSS→Results→Solution Data→Export Matrix Data

Solutions: 451	_tutorial - microst	rip						
Simulation:	Setup1	-	Sweep		•			
Design Variation:	000mil' trace, H='4'	nil' traca I ='0' traci	. \u/_'11 <i>1</i> 7₀	ii' waveport H−'115mil' wave	er vt. \v/='//19mil'	1 🖌		
Design Variation: 000mil' trace_H='4mil' trace_L='0' trace_W='114.7mil' waveport_H='115mil' waveport_W='419mil'								
Profile Converge	ence Matrix Data	Mesh Statistics						
S Matrix	Gamma			Export Matrix Data	1			
Y Matrix Zo ✓ Matrix Zo ✓ Display All Freqs. Edit Freqs Equivalent Circuit Export								
🗌 Z Matrix				Check Passivity				
Magnitude/Ph	ase(de <u>c</u> 💌		Daasiiriitu	Tolerance: .0001	_			
			Fassivity	Tolerance: [.0001				
Freq	S:1:1	S:2:1				^		
		(0.99075, -56.2						
2:1 (0.99075, -56.2)	(0.0074534, -1	56)					
1.1 (GHz) 1·1 (0.013702, 154)	(0.98986 -61.8						
	0.98986, -61.8)	(0.008686, -17						
ì		,	,					
1.2 (GHz) 1:1 (0.014081, 153)	(0.98897,67.4						
2:1 (0.98897, -67.4)	(0.010039, 17	4)					
1.3 (GHz) 1:1 (0.014506, 151)	(0.98808, -73)				-		
			Clos					





Reference:

- ECE 451: Planar Transmission Lines by Professor Jose E. Schutt-Aine
- ECE 546: ANSYS HFSS Tutorial by Tianjian Lu



