ECE 451 Automated Microwave Measurements

Homework #5 Due Wednesday, April 9, 2025

Introduction to HFSS

Part 1: Simple microstrip line

(http://emlab.illinois.edu/ece451/HFSS_tutorial_451.pdf)

Go through the HFSS tutorial available from the ECE451 course website. Attach <u>screenshots of your</u> <u>design</u>, as well as your <u>plots with comments/observations</u>. Also, look at the profile of your simulation by going to **HFSS Results Solution Data**. In the tab "**Profile**", you should be able to see information about meshing, elapsed time, memory usage, solved frequencies etc. In the tab "**Convergence**", you should be able to see the adaptive passes. Look for the following information in your profile and report it in your hand-in:

1. Look at "**Convergence**" tab, after how many passes did the solution converge? Include a plot of *Max Mag. Delta S* vs *Pass number*.

2. Look at "**Profile**" tab, list out the number of tetrahedra used when meshing the structure and the matrix size in each pass you answered above.

After the converged pass, HFSS started to solve the problem at multiple frequencies, how many frequencies at which the problem was solved? For each solved frequency, what was the matrix size?

You should see that the solved frequencies are grouped. After a group of frequencies are solved, HFSS calculated and report **"S Matrix Error**". Report the **"S Matrix Error**" evolution (you should see **"S Matrix Error**" getting smaller as more frequencies are solved)

Questions:

- 1. What is HFSS? Describe the benefits, features, applications of HFSS and why it is used so much in industry today?
- 2. What are the non-idealities of the interconnect at high frequencies, and how can they be modeled accurately?
- 3. Look at your simulated S-Parameter matrices from the HFSS tutorial
 - a. Is this two-port reciprocal? Why or why not?
 - b. Is this two-port lossless? Why or why not?

Part 2: A microstrip line with discontinuity in return path

In this section, you will learn the importance of the return path current to signal integrity. The simple microstrip line will be used again. This time, a cut-out in the ground plane will be made and we will study the effect of the cut-out to S-parameter of the line.

Open Ansys Electronics Desktop, insert a new HFSS project, save the file as "**seg_return.aedt**". Define variables as follows

Name	Value	Unit	Evaluat	Type	Description	Read	Hidden	Sweep
BW	12.5	mm	12.5mm	Design				
SW	1.25	mm	1.25mm	Design				v
GW	1.25	mm	1.25mm	Design				~
GL	7.5	mm	7.5mm	Design				~
BH	1.5748	mm	1.5748	Design				~
GstartX	-2.5	mm	-2.5mm	Design				~
GstartY	-2.5	mm	-2.5mm	Design				~
HAirBox	12.5	mm	12.5mm	Design				~
LAirBox	1.2*BL		60mm	Design				\checkmark
WAirBox	2.5*BW		31.25mm	Design				\checkmark

We will now create the mentioned microstrip line with a gap in the ground plane using a macro. The macro will draw the model for you:

- + create the substrate.
- + draw the ground plane.
- + draw the signal trace.
- + create a cut-out in the ground plane.
- + create a **lump port** at one end of the line, representing the excitation.
- + create a **termination** at the other end of the line as a 50Ω resistor.
- + create an air-box surrounding the structure and assign a radiation boundary on it.

To run a script from HFSS, go to **Tools > Run Script**, then browse to the *.py source code and select it.

Download the script here: <u>http://emlab.illinois.edu/ece451/hw/seg_return_py</u>

(copy the text over and name it 'seg_return.py')



- returnpath_gap - HFSSDesign1 - 3D Modeler - [returnpath_gap - HFSSDesign1 - Modeler]

After the code is executed, you should have the model similar with this



Set solution frequency to 10GHz, add a frequency sweep from 10MHz to 10GHz with 401 points. Before studying the gap effect, let's first center the gap by setting:

GstartX = -6.25mm and GstartY = -0.625mm

Take a screenshot of the model at this step for your report before moving on.

a. Gap length effects

You will now run a parametric sweep simulation with different gap length. Setup a parametric sweep using **Optimetrics** feature as follows

Analysis	p1 Parte	⊡⊡ Shee	boa Doa ts	rd CreateBox F		
	Paste	Ctil+V	Tect		KZ7-	
	Add	>	M.	Parametric	2	
⊕ ∰ Po	Analyze	,		Ontimization	e	
	View Analysis Result]	Sensitivity	Z	
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perties		×	8	Design of Experime	nts	
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Setup Sweep Analysis					×	
		1				
Sweep Definitions Tab	ile General Calculations Option	IS				
Sync # Add/E	dit Sweep				×	
		Mar	ahla	Deseri	ntion .	
Variable	GL 💌	GL	L	inear Step from 2.5mm	to 10mm,	
Nomina	al value: 7.5mm				e la	
C Sing	jle value	2				
Line	ar step	Add >>				
⊖ Line	ar count					
⊖ Dec	ade count	Update >>				
Operatic Octa	ave count					
C Exp	onential count	Delete				
Start:	2.5 mm 💌					
Sten	10	<			>	
Stop:						
Step:	2.5 mm 💌		OK	Ca	Incel	
	1					
Edit Variables • HPC and Analysis Options OK Cancel						

b. Gap location effects

Now we will investigate how the location of gap along signal flow will affect the trace impedance.

Note: If you choose to overwrite ParametricSetup1, data from part 2a will be deleted. Adding another ParametricSetup will keep your previous run data and only run new cases.

Add another parametric sweep from **Optimetrics** option to vary location of the gap.

Add/Edit Sweep

Variable GstartY ▼		Variable	Description
Nominal value: _0.625mm		GstartY	Linear Step from -20mm to 0mm, s
 Single value 			
 Linear step 	Add >>		
⊂ Linear count			
C Decade count	Update >>		
Octave count			
○ Exponential count	Delete		
Start: -20 mm 💌			
Stop: 0 mm 💌		<	>
Step: 5 mm 💌		0	K Cancel

Now you should have 2 parametric setups. **ParametricSetup1** is sweeping GL as above, while **ParametricSetup2** is sweeping GstartY we just added (you can rename them to make them distinguishable). You can disable 1 and run the other.



When **ParametricSetup1** is disabled, GL would be the nominal value specified in *Design Properties*.

c. Gap width effects

Now that you're familiar with **Optimetrics** simulation in HFSS, continue to investigate how the gap width would affect the trace impedance by sweeping GW

🔳 Add/Edit Sweep			×
Variable GW		Variable	Description
Nominal value: 1.25mm		GW	Linear Step from 0.5mm to 2mm, st
○ Single value			
Linear step	Add >>		
C Linear count			
C Decade count	Update >>		
C Octave count			
C Exponential count	Delete		
Start: 0.5 mm 💌			
Stop: 2 mm 💌		<	>
Step: 0.25 mm 💌		0	K Cancel

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Note: When plotting S-parameter, you can use tab "**Families**" to choose which design variations you want

Trac	Familie	es Families Display		
Far	milies : 7 a	• Available	Click here to cho design variatio	oose ons
	Variable		Value	E
	GW	All		
	GL	7.5mm		
	GstartY	-0.625mm		

Submit screenshots of the model at a few different design parameters and plots of S-parameters of all above sweeps and comment on the effects of the gap on the ground plane to the trace. Also include plots of the trace impedance (in this case, Z_{11}) to support your comments. You can get the Z parameters in HFSS by two ways:

- a. In the "**Matrix Data**" tab of the **Solution** window, you will be able to export Z matrix to touchstone format file along with S and Y parameter, then use another tool to read the file and post-process it.
- b. When creating plots in HFSS, you can directly request to plot Z parameter.

Questions:

- 1. Report the same quantities asked in question 2 of Part 1.
- 2. Include a final comment about the effect of a discontinuity in the return path current