Assignment: HW 2

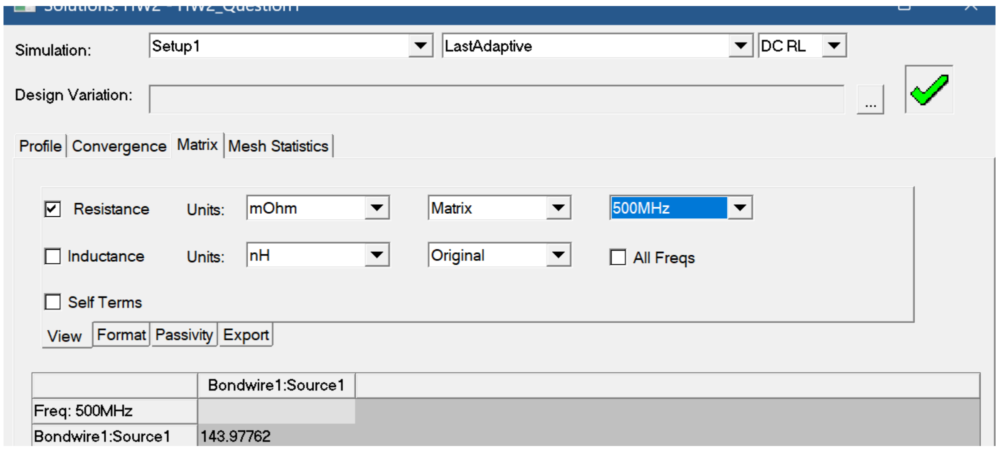
Class: ECE 5224

Name: Joshua Hopkins

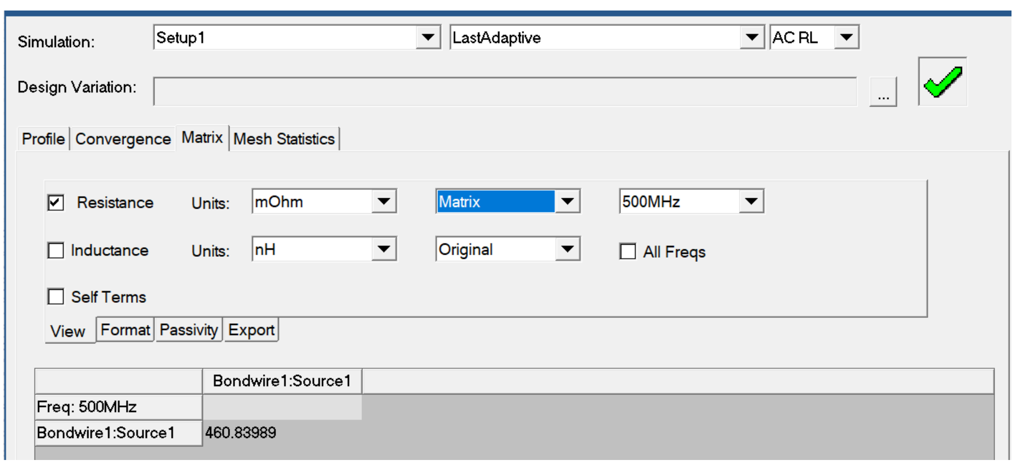
VT ID: Hopkinsjg1

Date: February 24th, 2025

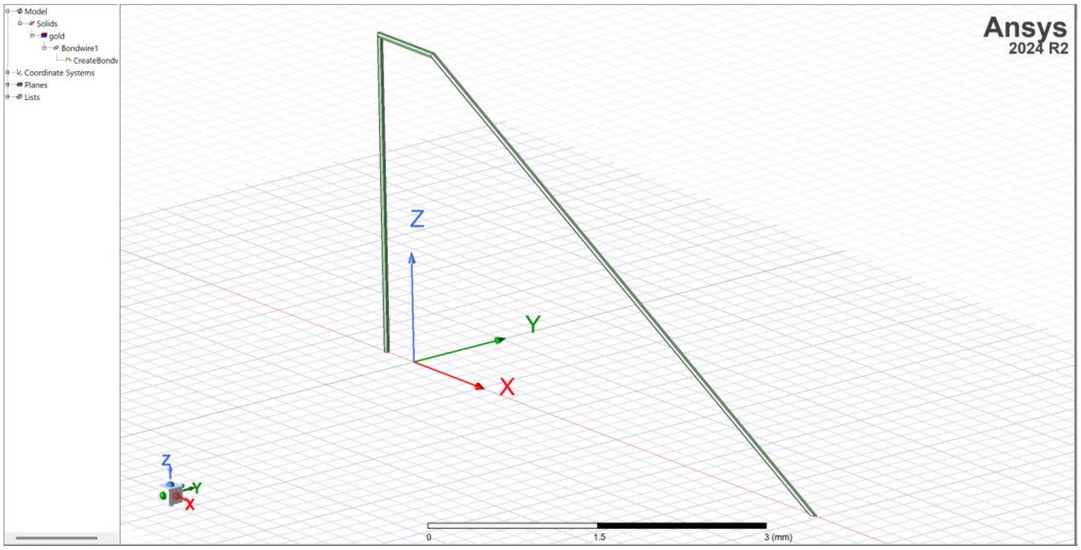
- Problem 1:
  - DC Resistance:



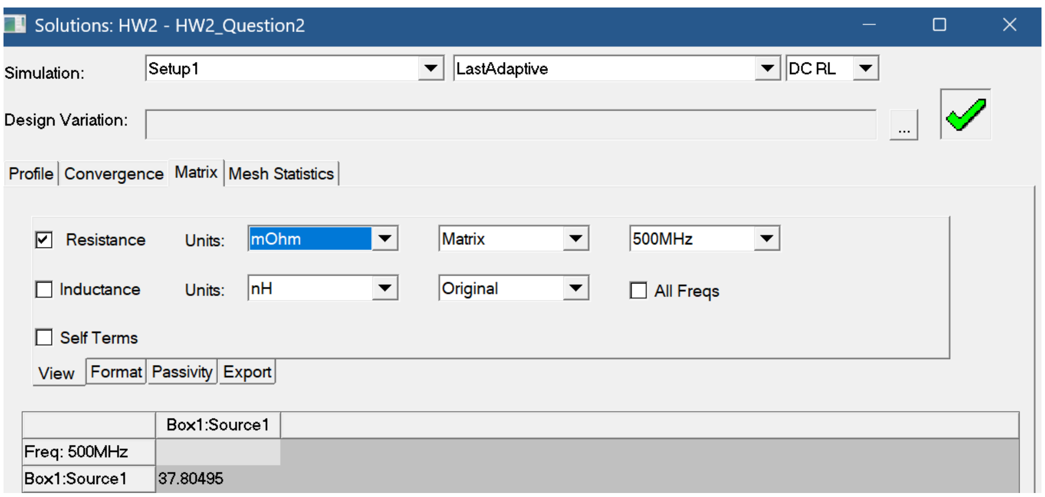
  - AC Resistance at 500 MHz:



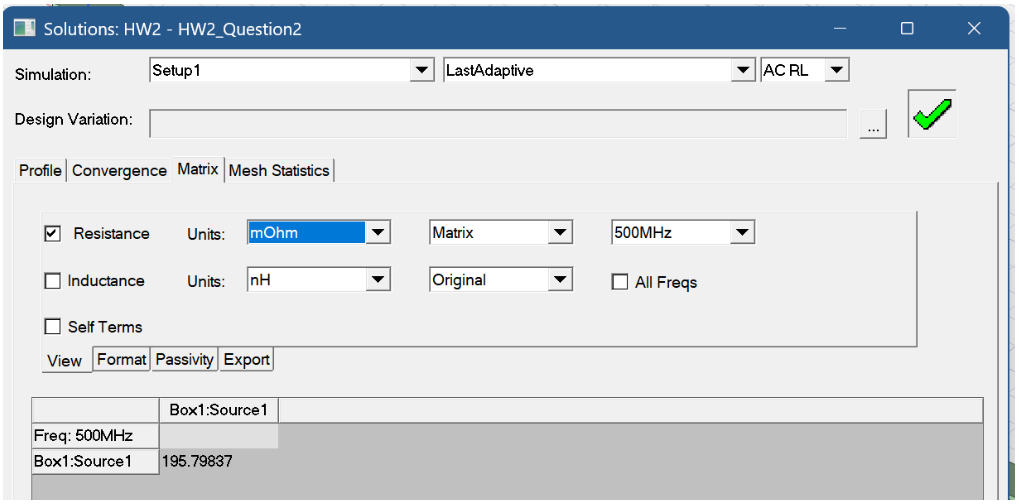
- Wire bond:



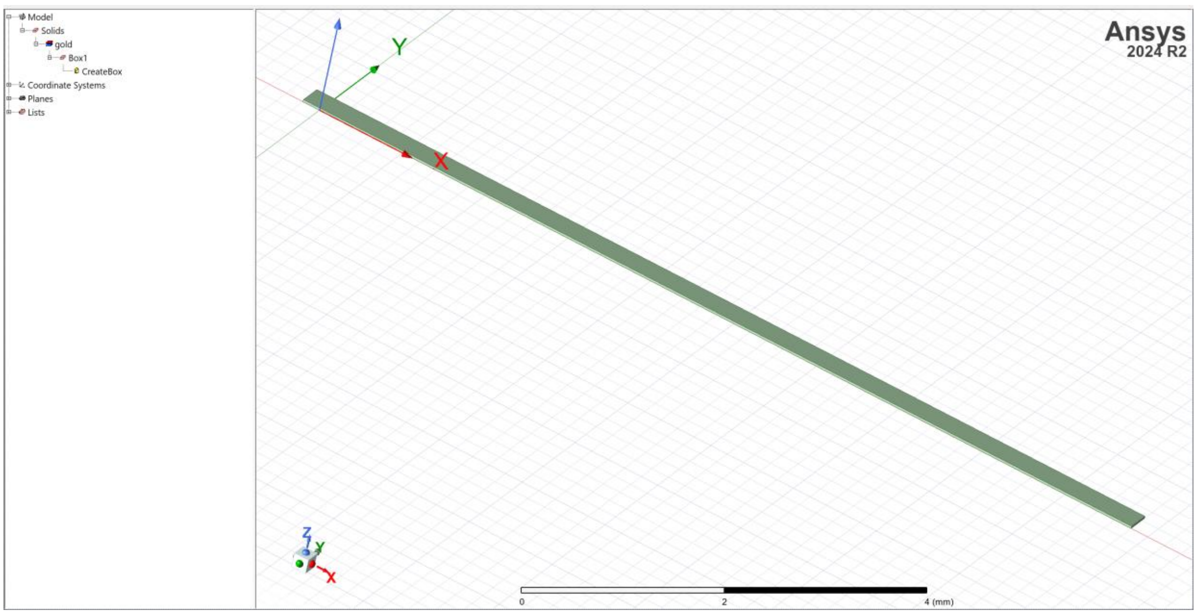
- Problem 2
  - Ribbon DC Resistance:



- Ribbon AC at 500 MHz:



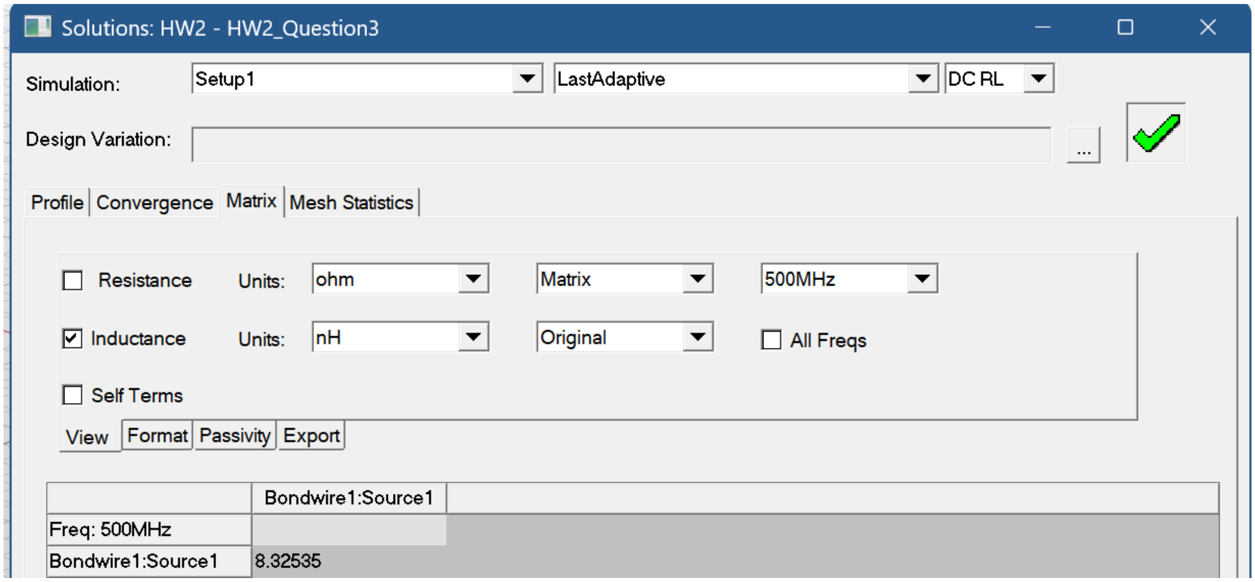
- Ribbon Bond:

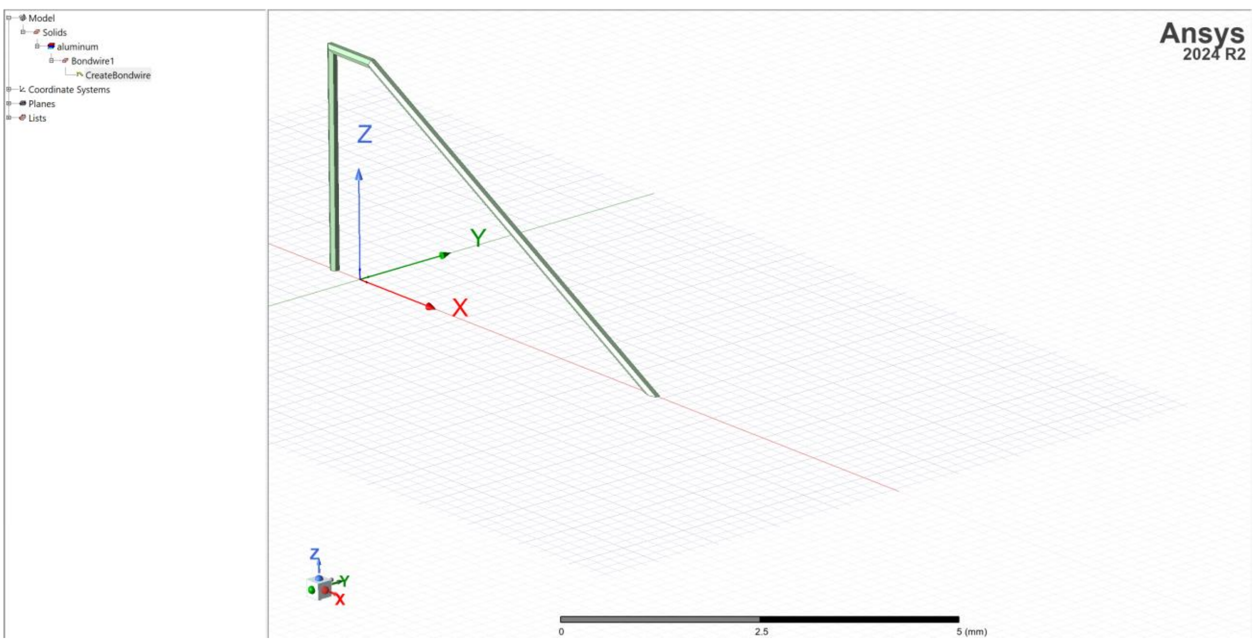


- Problem 1 and 2 Results:

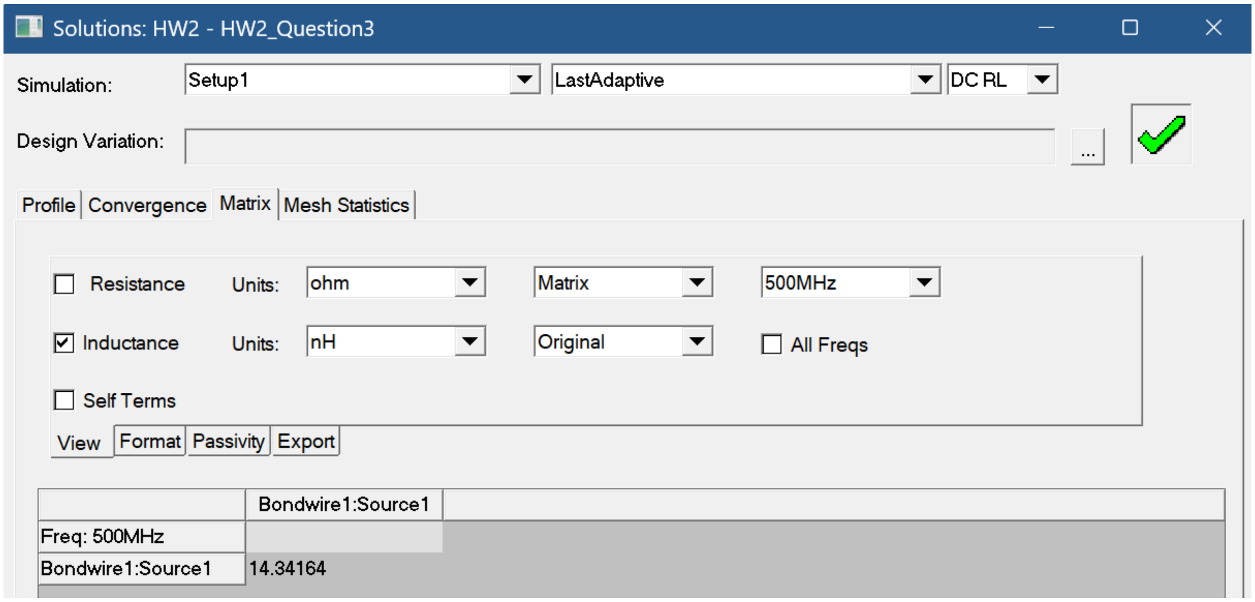
Component and Parameter	Calculation (mΩ)	ANSYS Q3D (mΩ)	Percent Error %
Wire Bond DC Resistance	120.4	143.977	16.3755322
Wire Bond AC Resistance at 500 MHz	467.3	460.83	1.403988456
Ribbon DC Resistance	37.8	37.804	0.010580891
Ribbon AC Resistance at 500 MHz	127.4	195.798	34.93294109

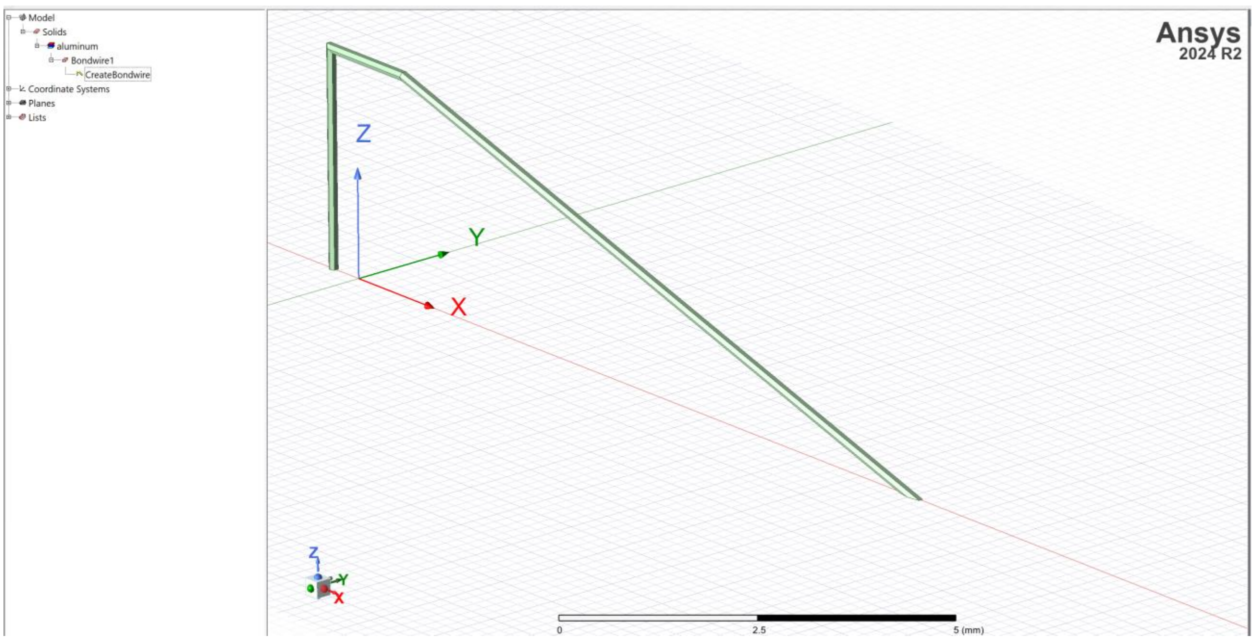
- Problem 3a:
    - Length 10mm:



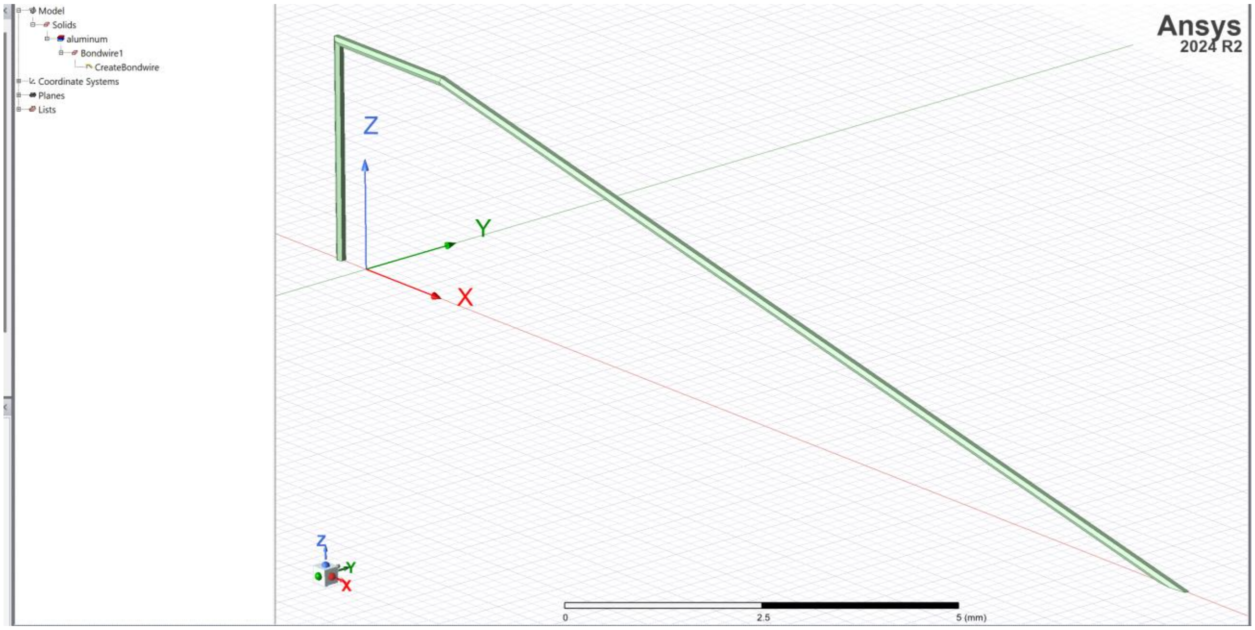


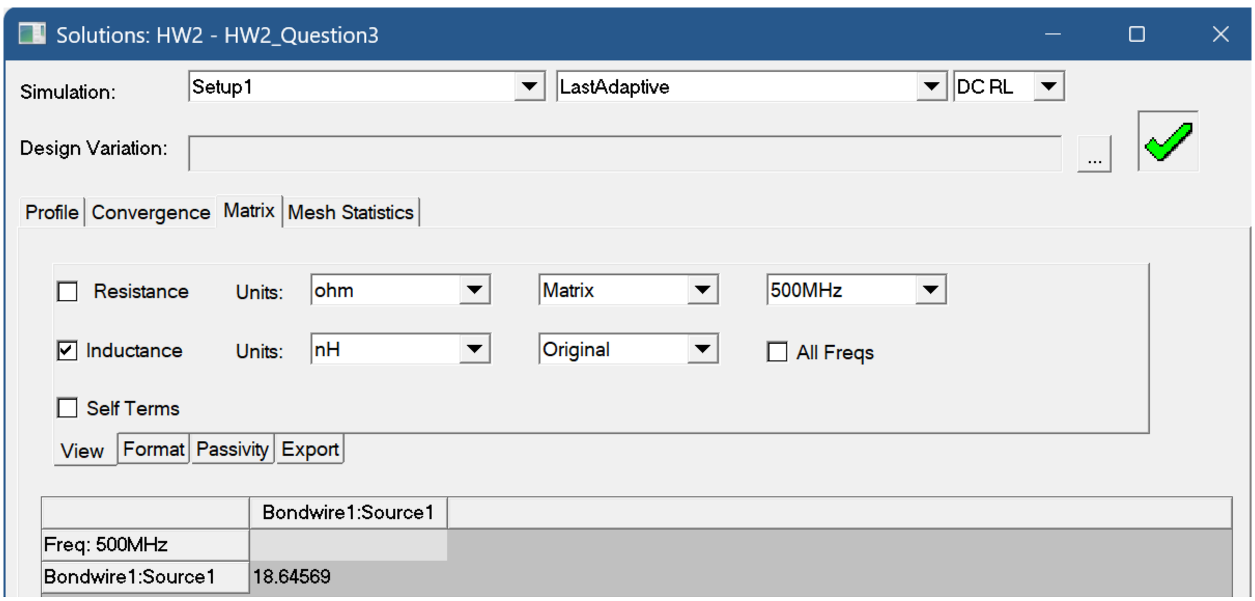
- Length 15mm:


Solutions: HW2 - HW2_Question3
Simulation:
Setup1
LastAdaptive
DC RL
Design Variation:
...
Profile
Convergence
Matrix
Mesh Statistics
Resistance
Units:
ohm
Matrix
500MHz
Inductance
Units:
nH
Original
All Freqs
Self Terms
View
Format
Passivity
Export
Bondwire1:Source1
Freq: 500MHz
Bondwire1:Source1
14.34164


Model
Solids
aluminum
Bondwire1
CreateBondwire
Coordinate Systems
Planes
Lists
Ansys
2024 R2
Z
Y
X
0
2.5
5 (mm)

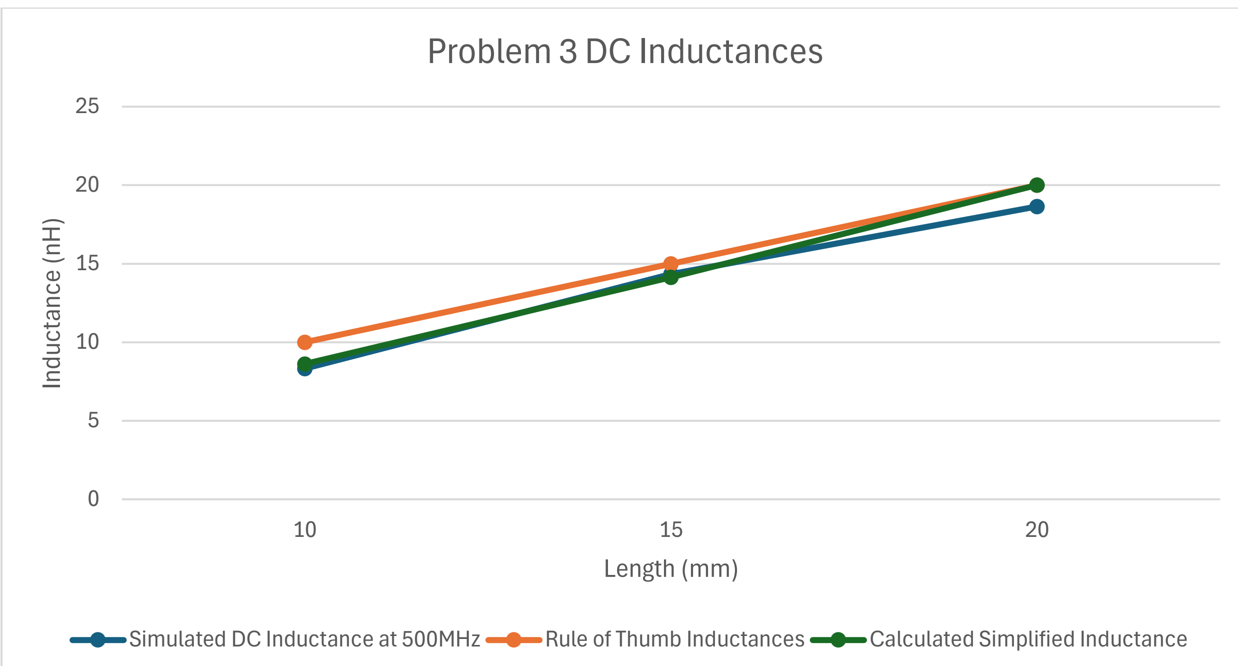
- Length 20mm:


Model
Solids
aluminum
Bondwire1
CreateBondwire
Coordinate Systems
Planes
Lists
Ansys
2024 R2
Z
Y
X
0
2.5
5 (mm)


Solutions: HW2 - HW2_Question3
Simulation: Setup1 LastAdaptive DC RL
Design Variation:
Profile Convergence Matrix Mesh Statistics
Resistance Units: ohm Matrix 500MHz
Inductance Units: nH Original All Freqs
Self Terms
View Format Passivity Export
Bondwire1:Source1
Freq: 500MHz
Bondwire1:Source1 18.64569

- Problem 3a Results and Plot:

Length (mm)	Simulated Inductance at 500 MHz (nH)
10	8.325
15	14.341
20	18.645
Length (mm)	**Calculated Simplified Inductance (nH)**
10	8.618600932
15	14.14429672
20	20.00979059
Length (mm)	**RoT Inductance (nH)**
10	10
15	15
20	20

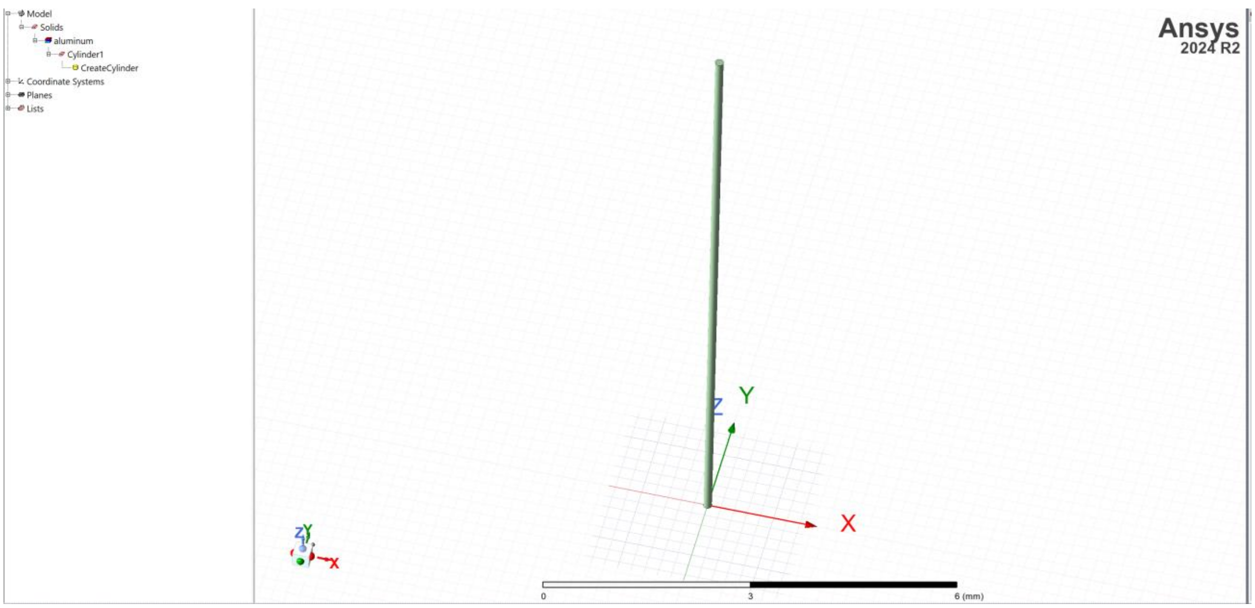


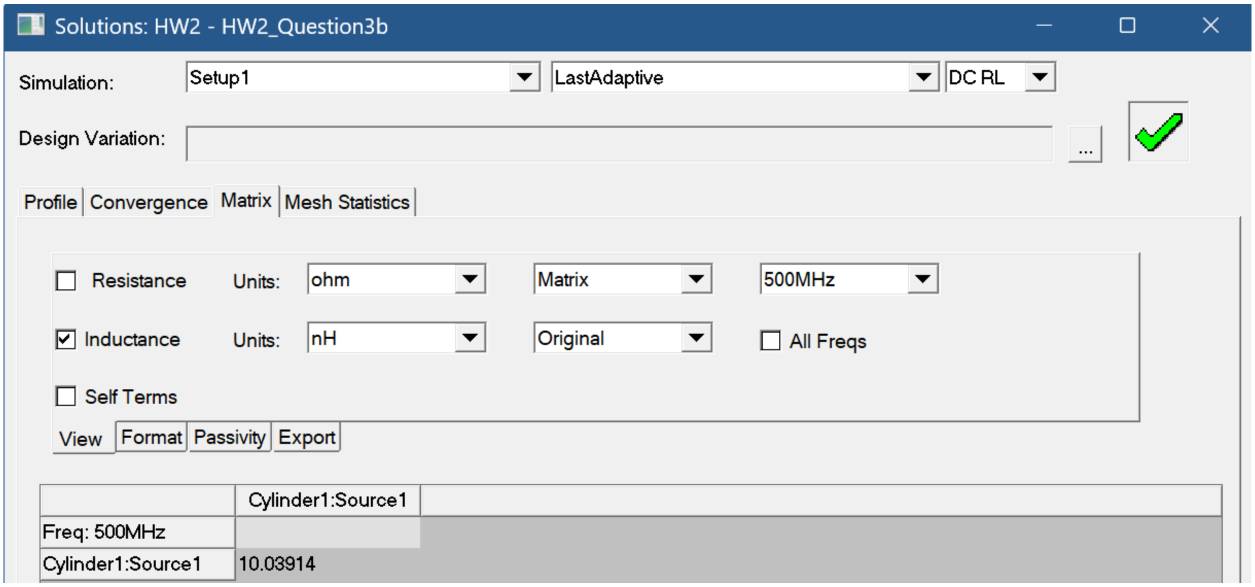
- Problem 3b:

I believe the reason why the simulated values are less in most cases and more in one case is since the simulation is taking the actual bond material and all of the extra parameters of the wire, seen below, into detail when performing the analysis.

Name	Value	Unit	Ev
Command	CreateBondwire		
Coordinate Sy...	Global		
Type	JEDEC 4-Point		
Pad position	-0.5 ,0 ,0	mm	-0.
Direction	0.9 ,0 ,0	mm	0.9
Distance	16.7	mm	16
H1	3	mm	3m
H2	0	mm	0m
Diameter	5	mil	5m
Number of Fa...	6		6
Axis	Z		
Reverse Direc...	☐		

The simulation is also being run at a 500 MHz frequency and is probably considering the skin and proximity effects of the wire bond. When using the RoT, it's not considering anything b/c the wire bond is the "ideal" wire in this case. Below you can see the results for an "ideal" bond with no bends and how the length is basically the same as the inductance.

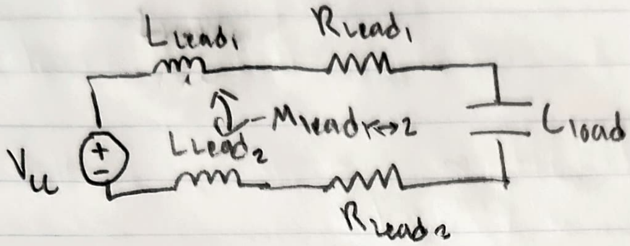



Solutions: HW2 - HW2_Question3b
Simulation:
Setup1
LastAdaptive
DC RL
Design Variation:
Profile
Convergence
Matrix
Mesh Statistics
Resistance
Units:
ohm
Matrix
500MHz
Inductance
Units:
nH
Original
All Freqs
Self Terms
View
Format
Passivity
Export
Cylinder1:Source1
Freq: 500MHz
Cylinder1:Source1
10.03914

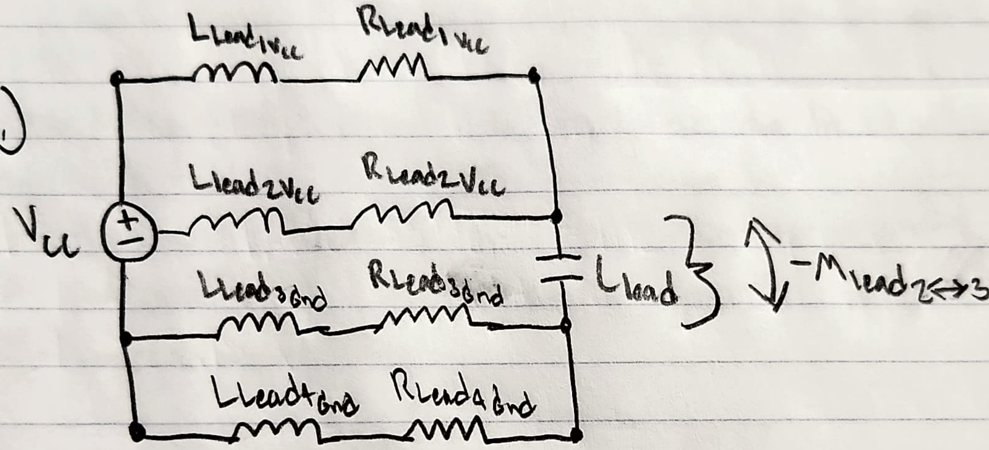
ECE 5229 Hopkins;jg1

4. Problem 4:

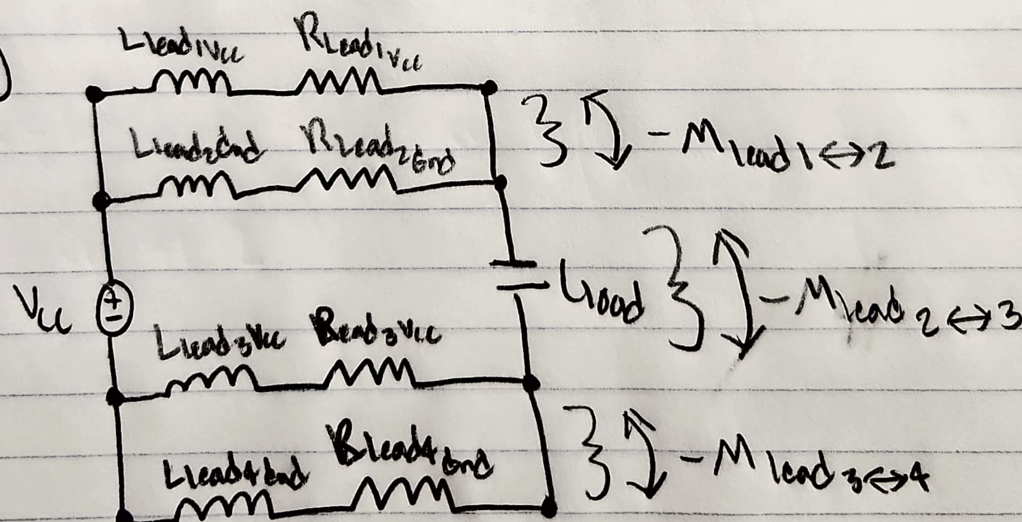
a)



b)



c)



Problem 4:

b.)

case A: $L_{Total} = 2_{Lead} - 2M_{Lead}$ Rank: Highest

case B: $L_{Total} = 4_{Lead} - 2M_{Lead}$ Rank: Middle

case C: $L_{Total} = 4_{L_{Lead}} - 2(3M_{Lead})$ Rank: Lowest

- Case A has the highest total inductance due to it only having 1 lead for both the V_{cc} and GND. This allows for a limited mutal inductance and less self inductance than the other cases. Not to mention that its not splitting its current source like the other 2 giving it a higher inductance to maintain.

ECE 5224 Hopkins'gl
Problem 5:

$l = 1cm$, $f = 1GHz$, rise time $= 100\,ps$, and $\varepsilon_r = 4.4$

$t_r = 100\,ps \Rightarrow 100ps \leq 33.33\sqrt{4.4}(2)(1)$
≤ 139.827 ✓

- The transmission line effects should be considered b/c the rise time (100 ps) is less than the calculated time delay (139.827 ps).

length $> 0.5t_r / (33.33)\sqrt{\varepsilon_r}$
$\Rightarrow l > 0.5(100)/(33.33)\sqrt{4.4}$
$\Rightarrow l > 0.715$ ✓

- The assumption also holds up when using the length method.

ECE 5224 Hopkinsjgl

Problem 6

$.015cm$ $\qquad$ $.002cm$

line width = $150\,\mu m$, signal line thickness = $20\,\mu m$,

dielectric thickness = $200\,\mu m$, dielectric constant = $4.0 = \varepsilon_r$

$.02cm$

$$v_p = \frac{c}{\sqrt{\varepsilon_r \mu_r}} \text{ [m/s]}$$

1.) microstrip line: $b = 200\,\mu m$ and $a = 150\,\mu m$

$.02cm$ $\qquad$ $.015cm$

$$\varepsilon_{eff} = \varepsilon_0 \left[\frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \cdot \frac{1}{\sqrt{1+12(b/a)}} \right] = 8.854E\text{-}14 \left[\frac{4+1}{2} + \frac{4-1}{2} \cdot \frac{1}{\sqrt{1+12(.02/.015)}} \right]$$

$$= 8.854E\text{-}14 [2.5 + 1.5 \cdot .2425] = 2.54E\text{-}13$$

$$v_p = \frac{1}{\sqrt{\mu \varepsilon_{eff}}} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_{eff}}} = \frac{1}{\sqrt{4\pi E\text{-}8 \cdot 1 \cdot 2.54E\text{-}13}} \approx \boxed{5.597 \cdot 10^9 \text{ cm/s}}$$

$$a < b \Rightarrow Z_0 = \frac{1}{2\pi} \sqrt{\frac{\mu}{\varepsilon_{eff}}} \ln\left(\frac{8b}{a} + \frac{a}{4b}\right) = \frac{1}{2\pi} \sqrt{\frac{4\pi E\text{-}8}{2.54E\text{-}13}} \ln\left(\frac{8(.02)}{.015} + \frac{.015}{4(.02)}\right)$$

$$= 266.94\,\Omega$$

Problem 6

2) embedded microstrip line

$w = .015\text{cm}$, $t = .002\text{cm}$, $h = .02\text{cm}$

$$v_p = \frac{1}{\sqrt{\mu \varepsilon}} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} = \frac{1}{\sqrt{(4\pi E{-}8)(1)(8.854E{-}14)(4)}}$$

$$= \boxed{4.74E9 \text{ cm/s}}$$

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r + 1.41}} \ln\left(\frac{5.98h}{0.8w+t}\right) = \frac{60}{\sqrt{4+1.41}} \ln\left(\frac{5.98(.02)}{0.8(.015)+.002}\right)$$

$$= \boxed{55.33\ \Omega}$$

3) stripline: $b = .02\text{cm}$ and $a = .015\text{cm}$

$$v_p = \frac{1}{\sqrt{\mu \varepsilon}} = \boxed{4.74E9 \text{cm/s}}$$

$$0.35b = 0.35(.02) = .007 < a = a_{eff} = a$$

$$Z_0 = \frac{30\pi}{\sqrt{\varepsilon_r}} \frac{b}{a_{eff} + 0.441(b)} = \frac{30\pi}{\sqrt{4}} \cdot \frac{.02}{.015 + .441(.02)}$$

$$= \boxed{39.57\ \Omega}$$

- The microstrip line has the highest propagation velocity b/c it's not fully embedded allowing for a higher signal propagation thanks to the mixture of air and dielectric.