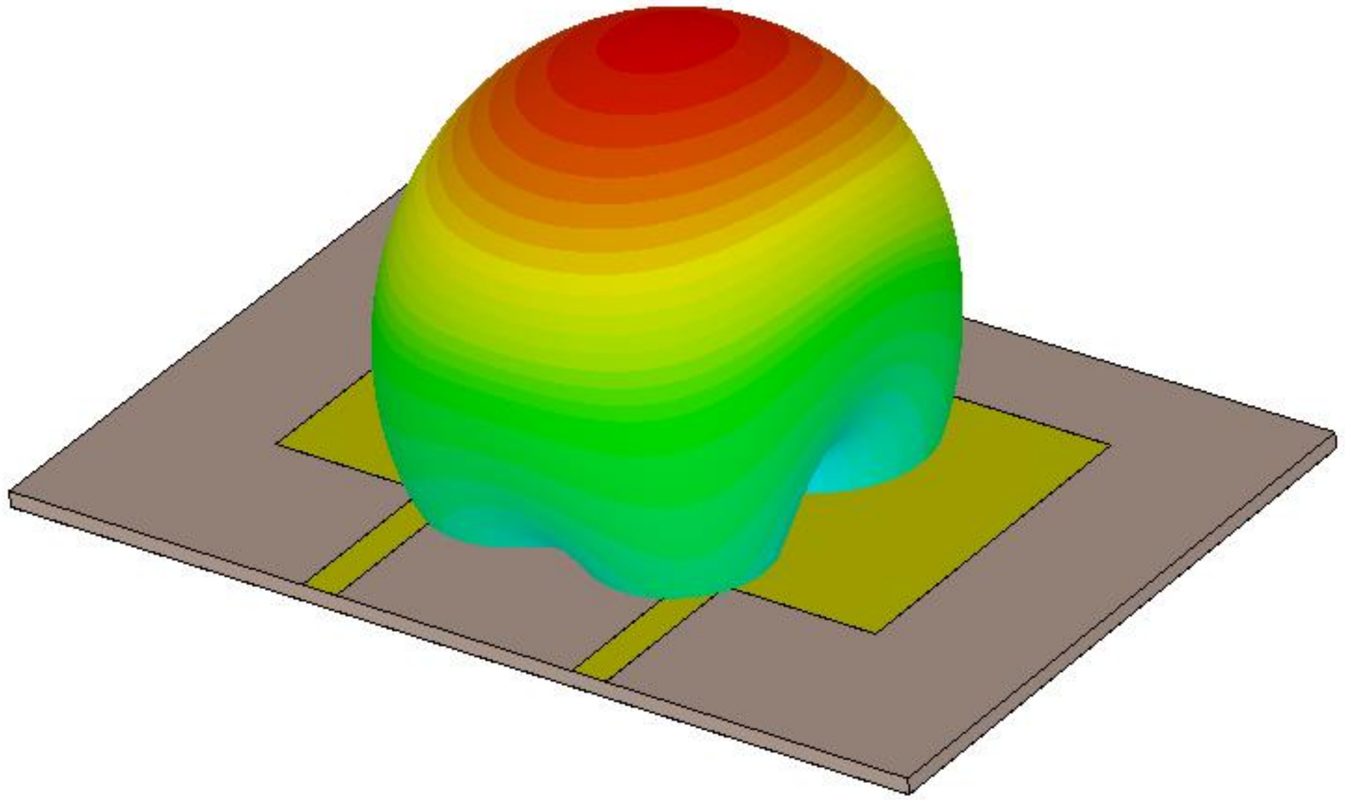
Workshop 2: Dual Patch Antenna and Feeding Network

Task Construct a dual patch antenna and a corresponding matching network.

Keywords Patch, Farfield, Schematic, Connector.

The dual patch array is an array of two microstrip patches, delivering increased directivity and aperture size compared to the single patch antenna.



The aim of this exercise is to go thru three main steps:

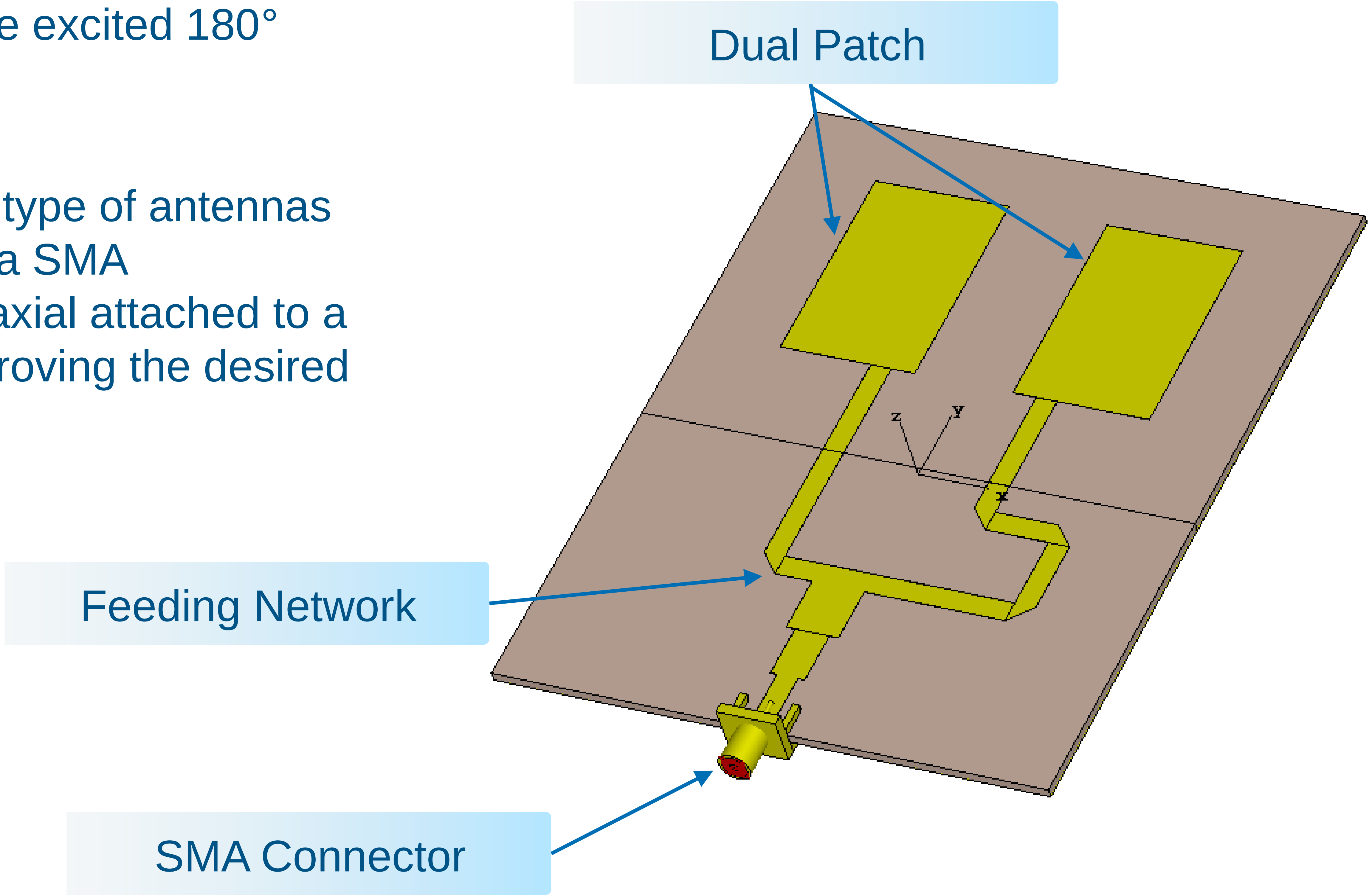
1. Dual Patch Antenna construction and simulation.
2. Feeding Network design and simulation.
3. Antenna + Feeding Network + Connector simulation.

90 min

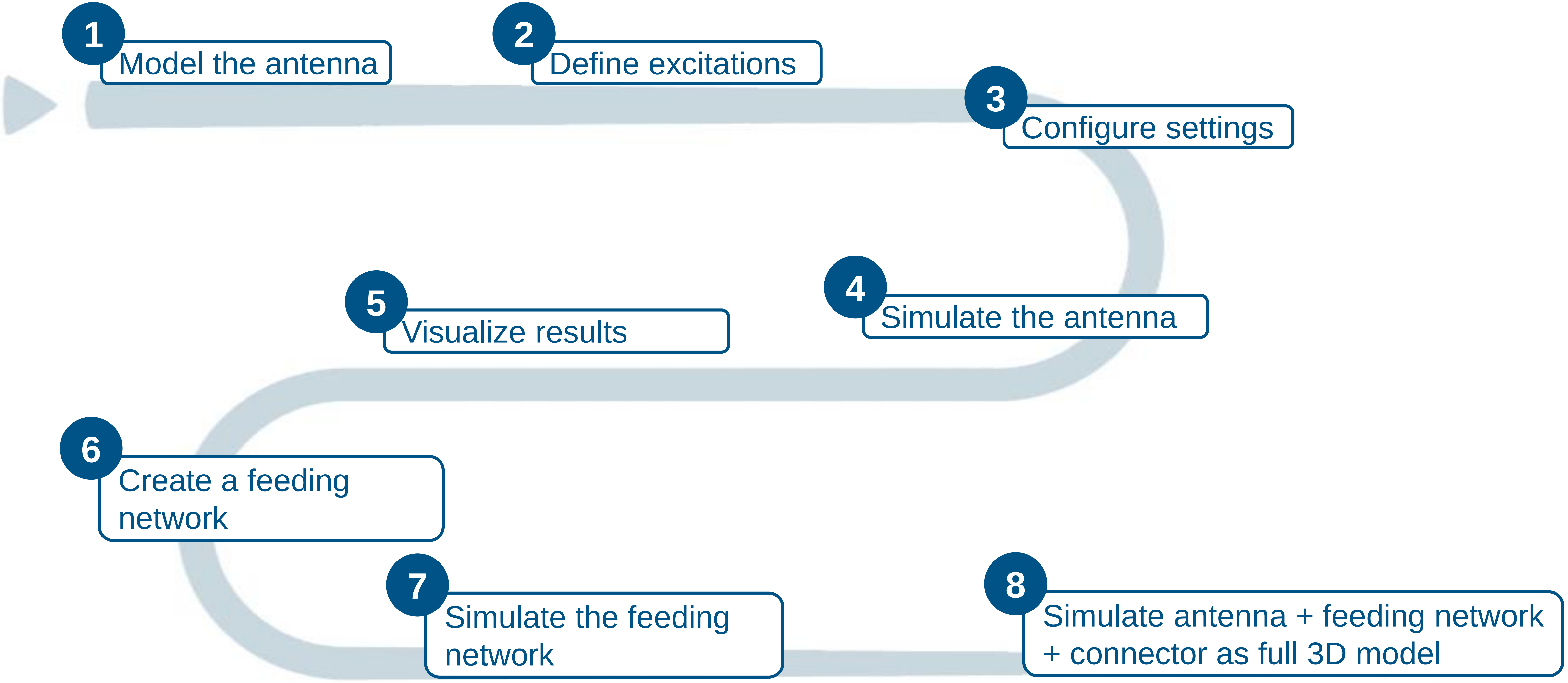
Final Model

The patches are optimized in a mirrored configuration and, in order to align their polarizations, the patches are excited 180° out of phase.

In practical realization these type of antennas are very often excited using a SMA (SubMiniature version A) coaxial attached to a microstrip feeding network proving the desired phase shift.

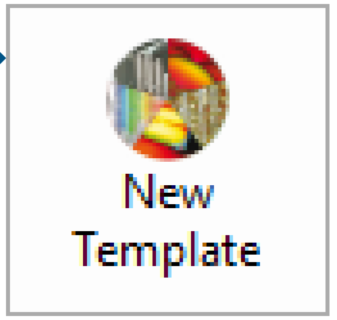


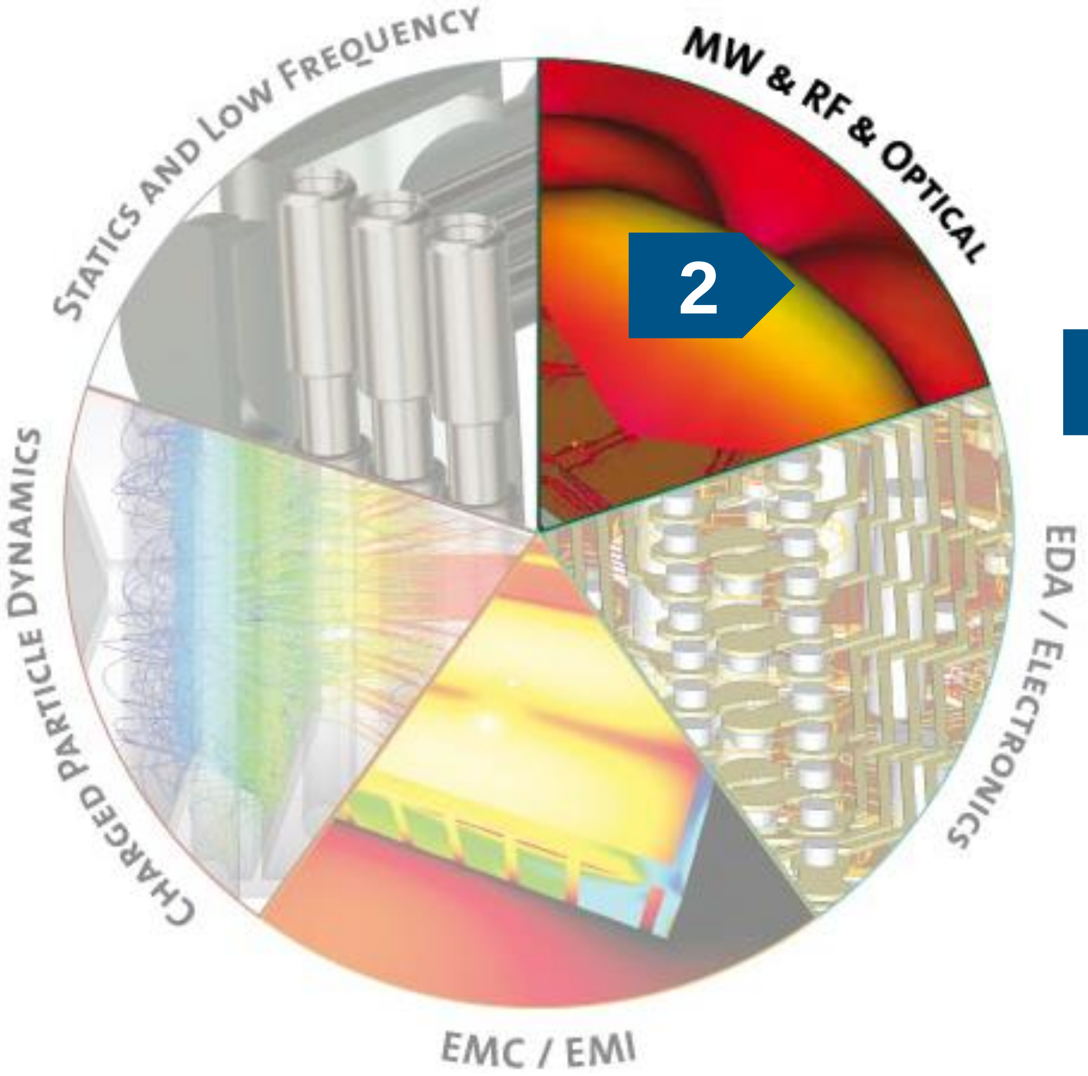
Workflow using CST STUDIO SUITE

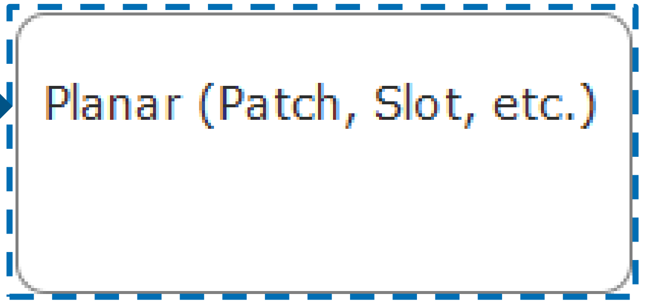


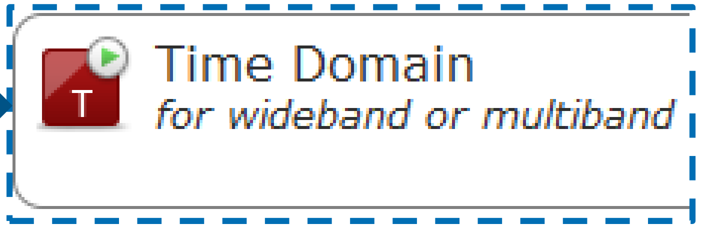
Create a New Template (1/2)

1. Create a **New Template.**
2. Select **Microwaves & RF & Optical.**
    a. Antennas.
    b. Planar.
    c. Time Domain.









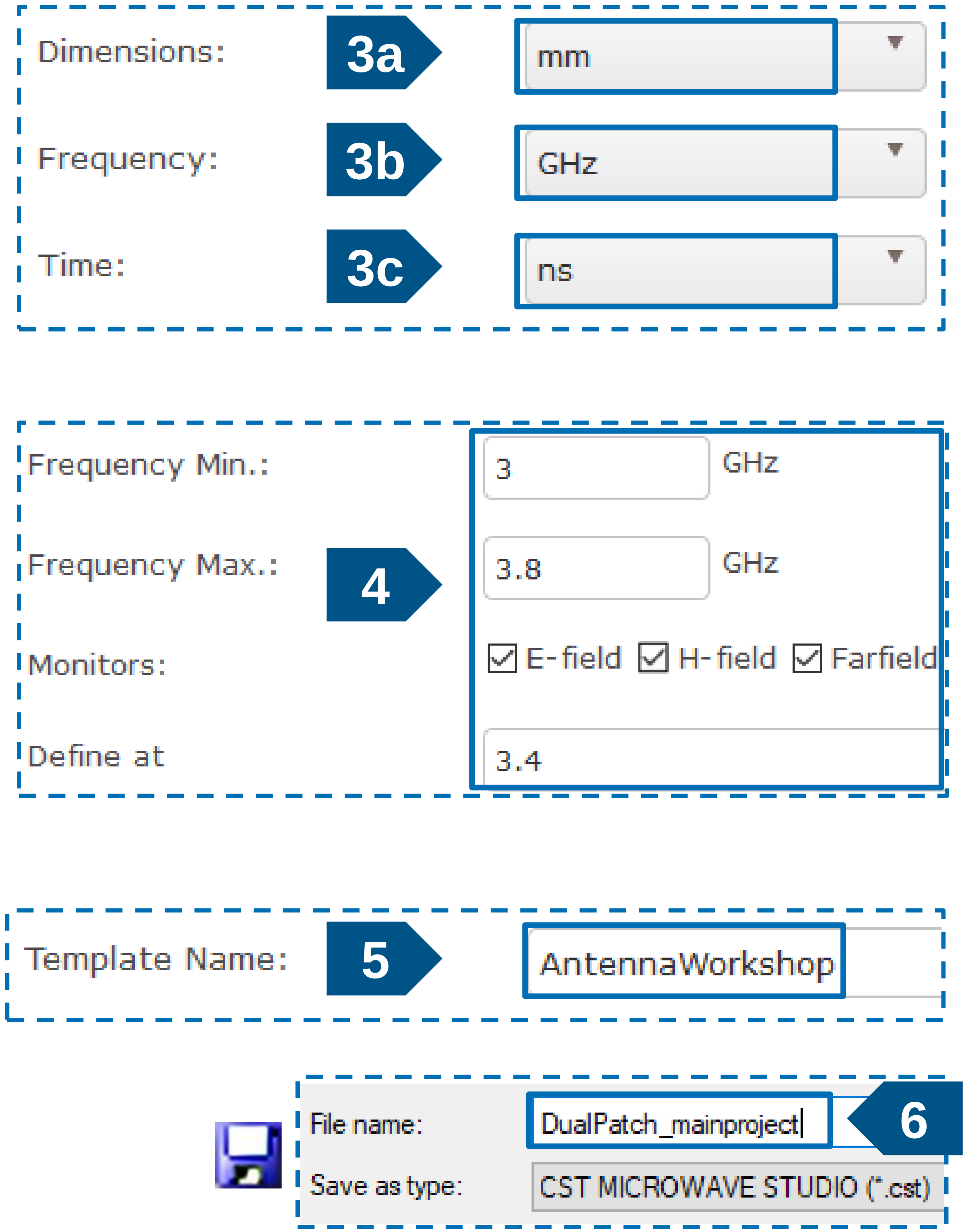
Create a New Template (2/2)

3. Specify the **units**:
    a. Dimensions.
    b. Frequency.
    c. Time.

4. Define the **frequency range** and **field monitors.**

5. Rename the template to **AntennaWorkshop.**

6. Save the project as **DualPatch_mainproject.**

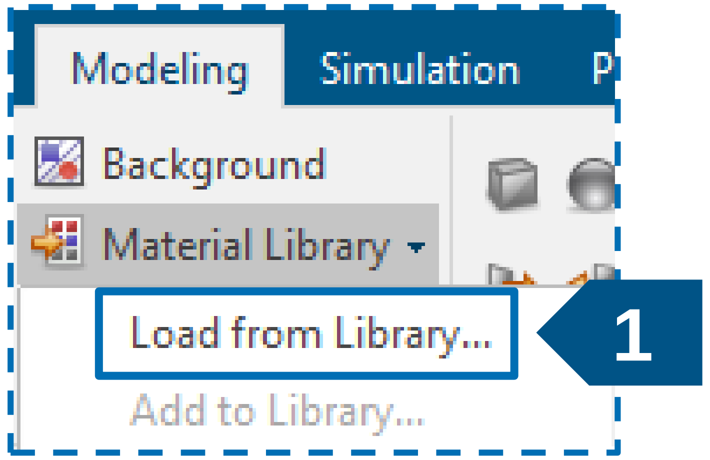


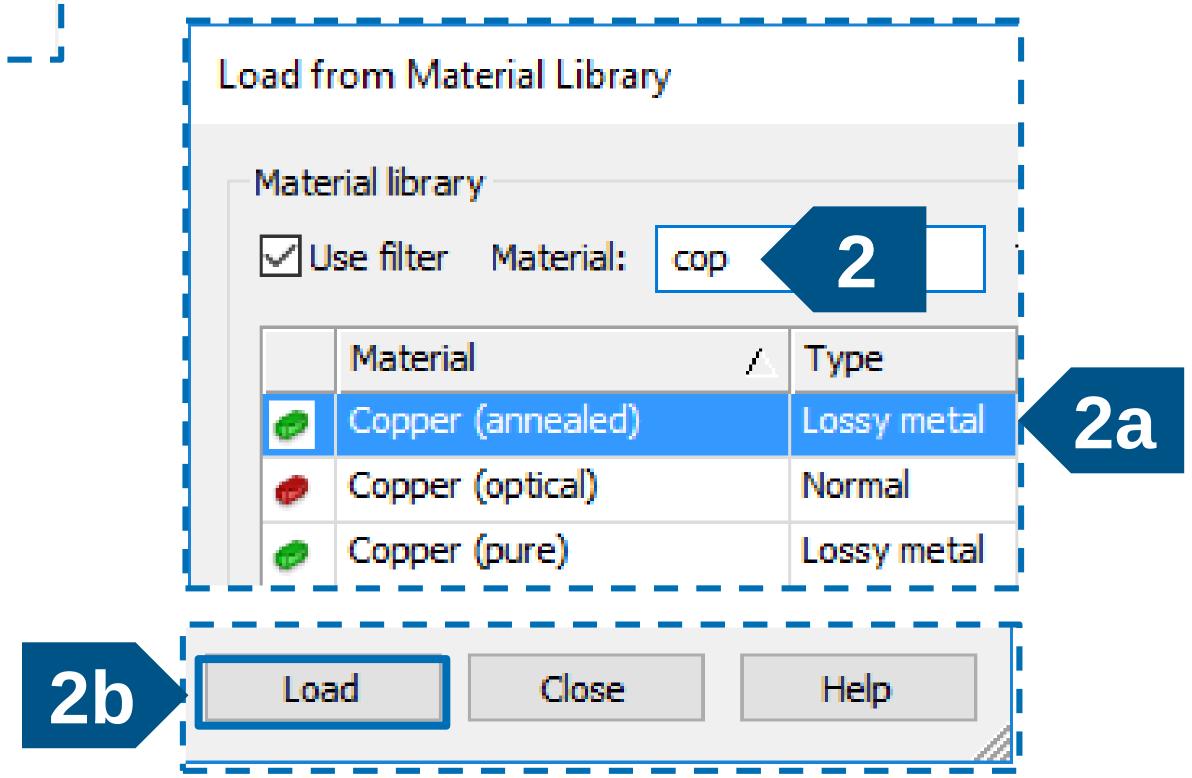
Load Materials

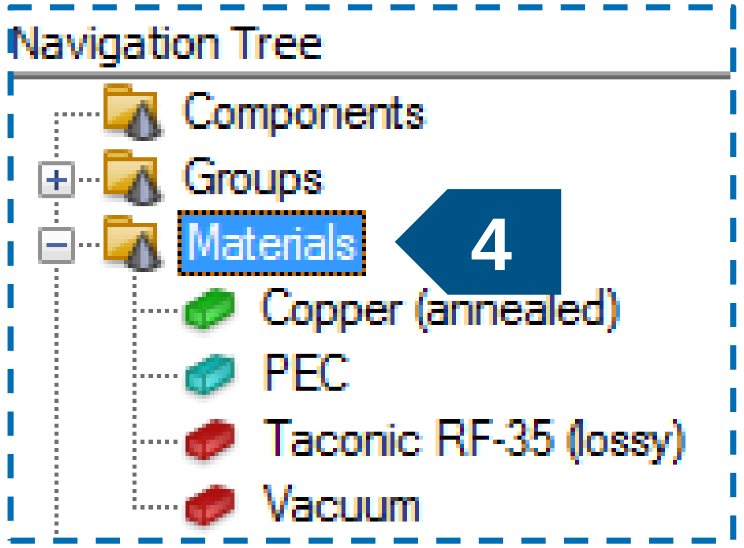
1. Navigate to **Material Library > Load from Library**

2. Type **“Cop”** to filter desired material.
   a. Select **Copper(annealed)**.
   b. Load Material.
3. Load **Taconic RF-35 (lossy)** in a similar way following step 1 and step 2.

4. The loaded materials are visible under the folder **“Materials”** of the Navigation Tree.





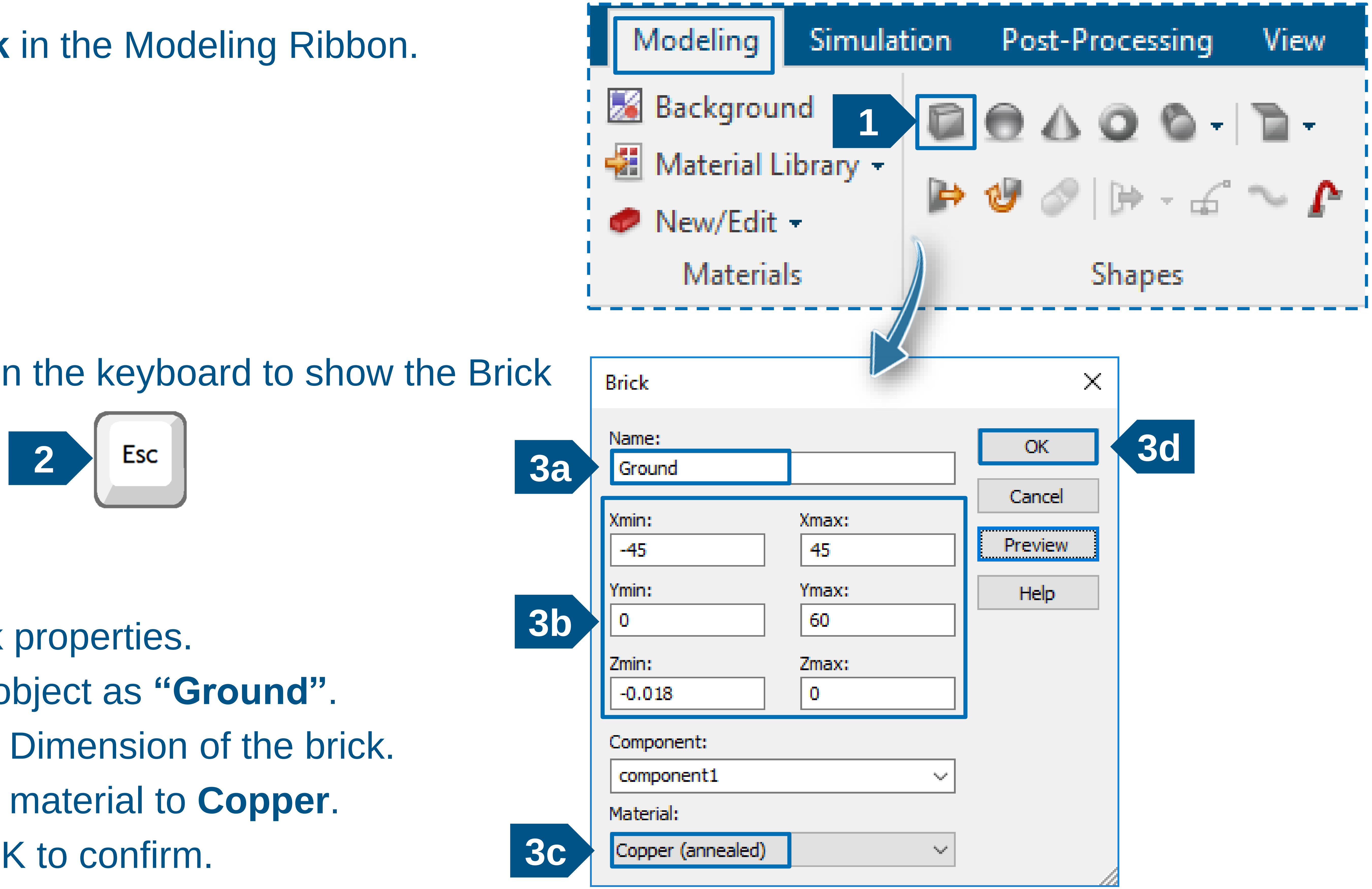


Model the Ground Plane

1. Select **Brick** in the Modeling Ribbon.

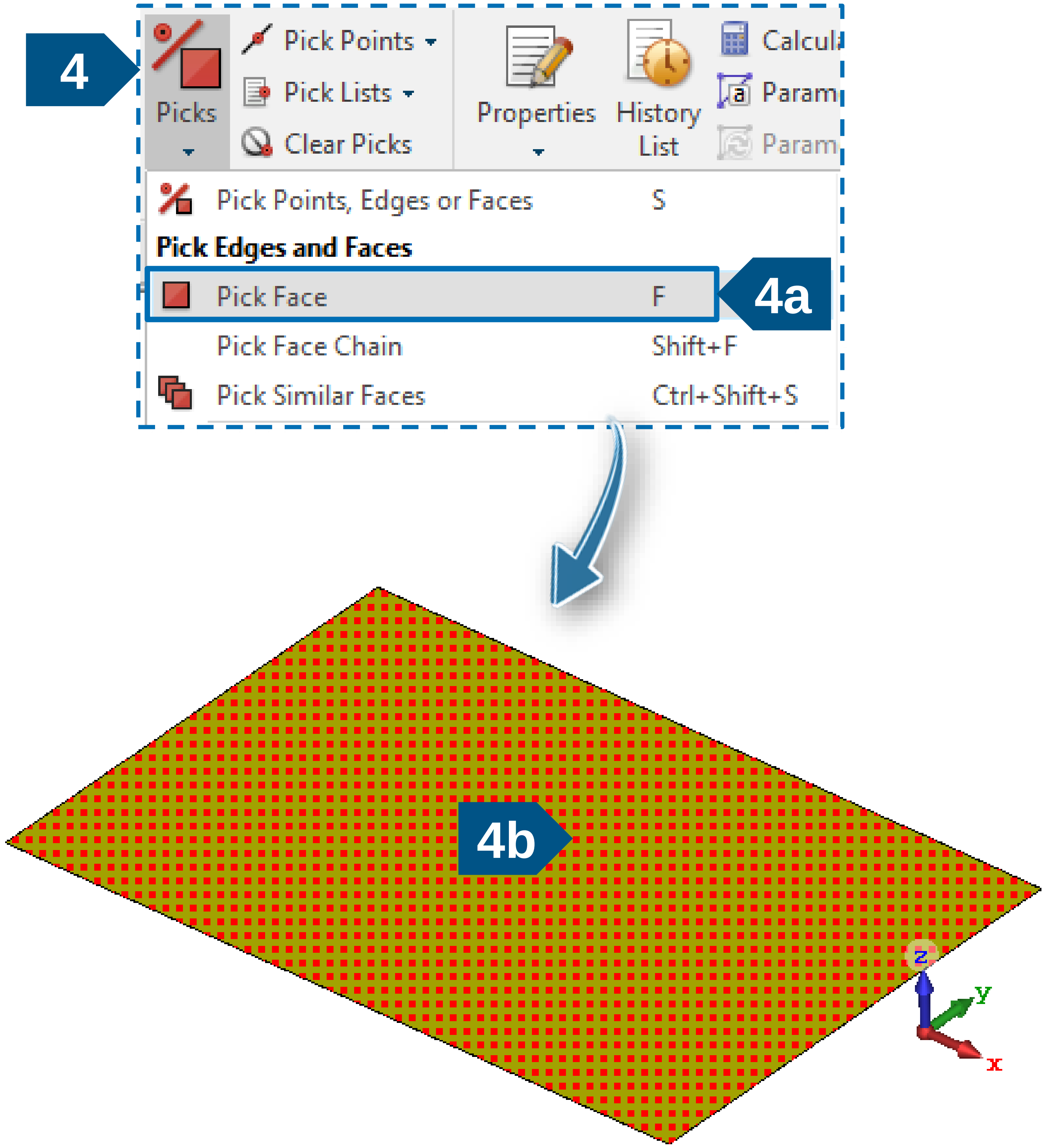
2. Click **ESC** on the keyboard to show the Brick dialog box.

3. Define Brick properties.
    a. Name object as **“Ground”**.
    b. Set the Dimension of the brick.
    c. Set the material to **Copper**.
    d. Click OK to confirm.



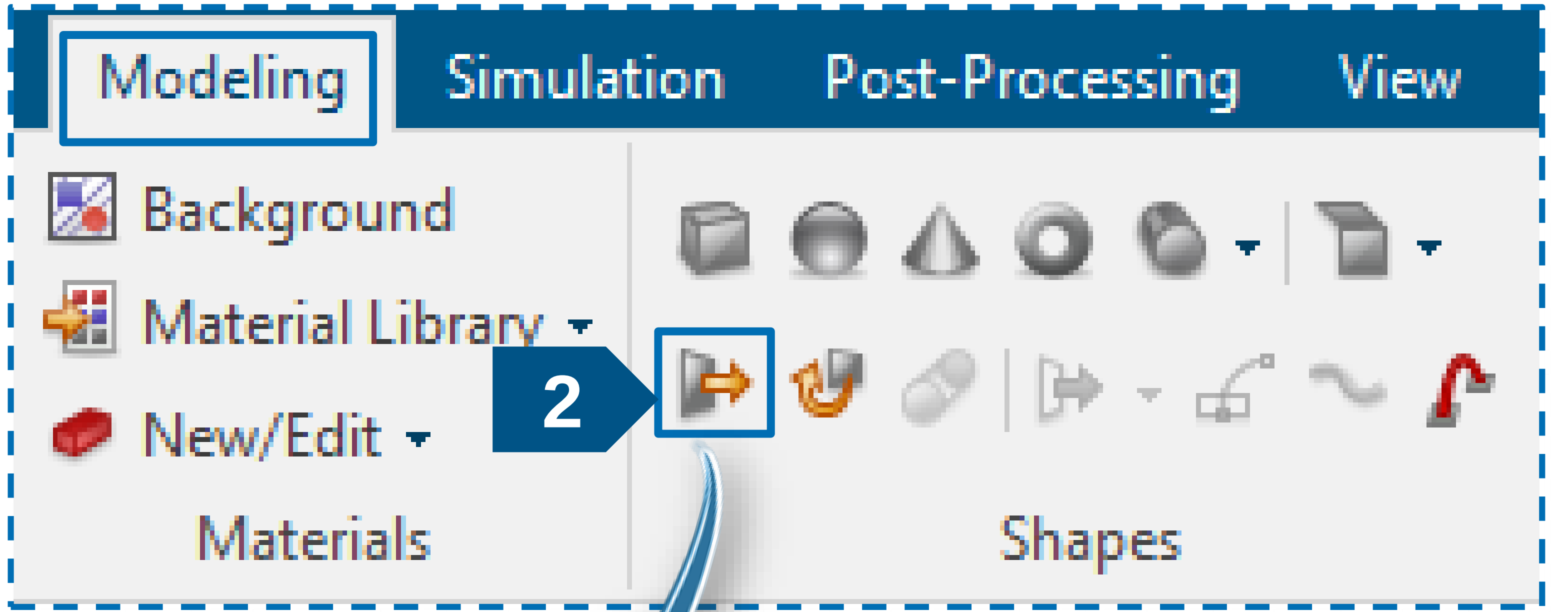
Model the Substrate (1/2)

1. Open Picks Menu.
    a. Enable **Pick Face (f)** mode.
    b. Double click on top of the ground plane (positive z-direction).

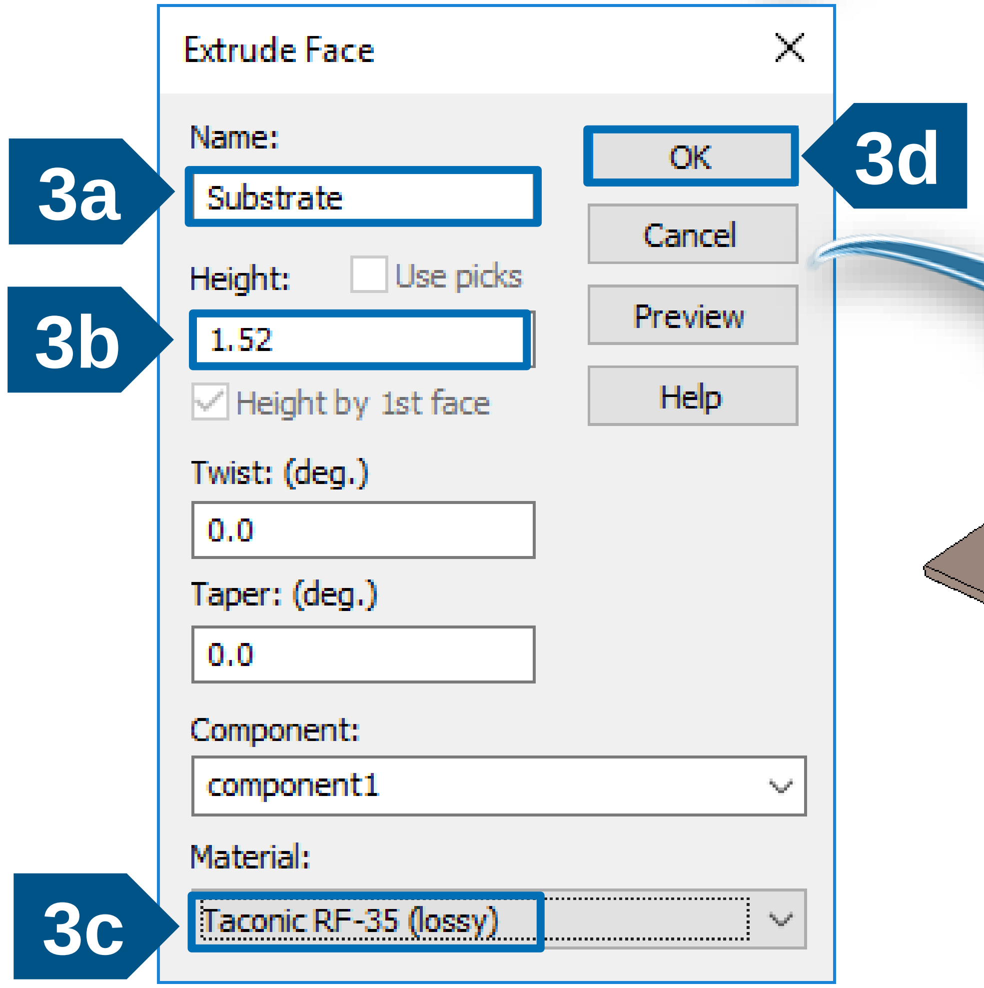


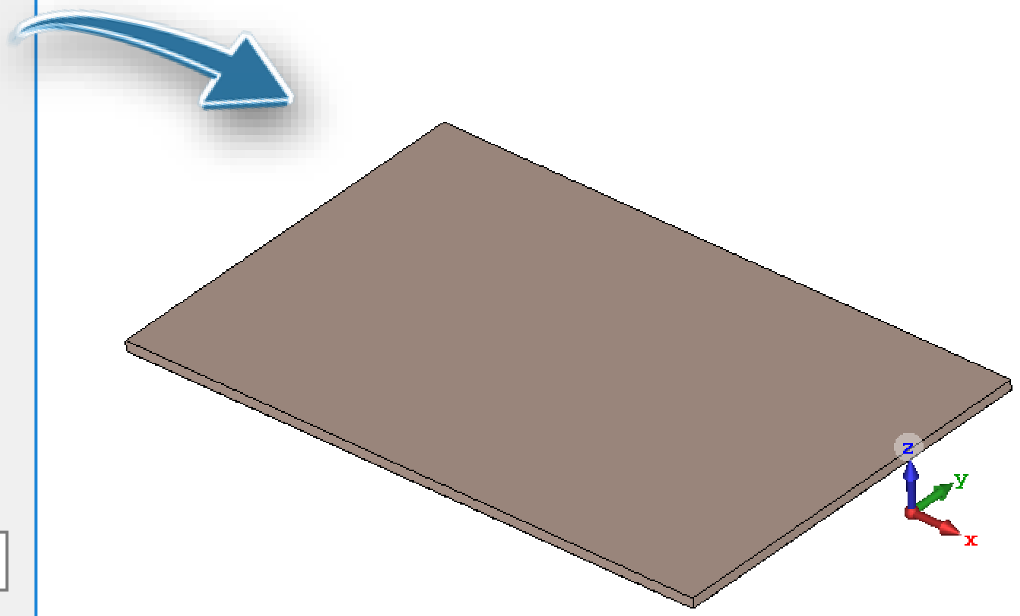
Model the Substrate (2/2)

2. Select **Extrude Face** in the Modeling Ribbon.



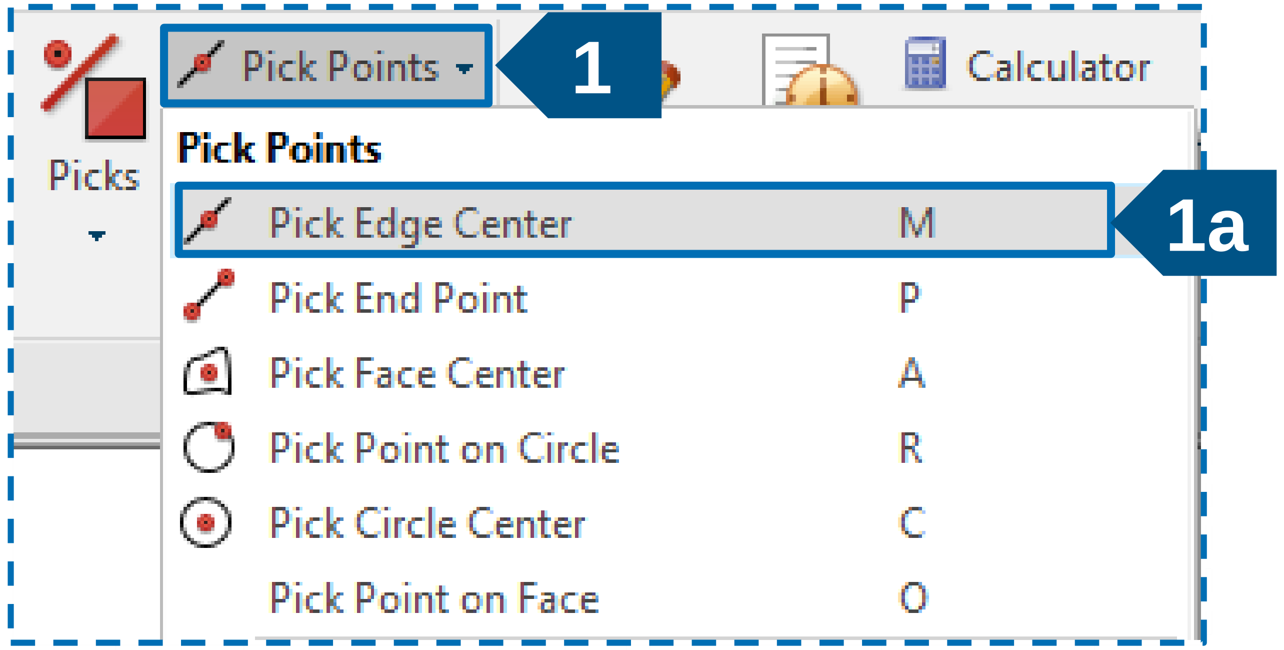
3. Specify substrate properties.
    a. Name object as **“Substrate”**.
    b. Set the height of the extrusion.
    c. Set the material to **Taconic RF-35**.
    d. Click OK to confirm.

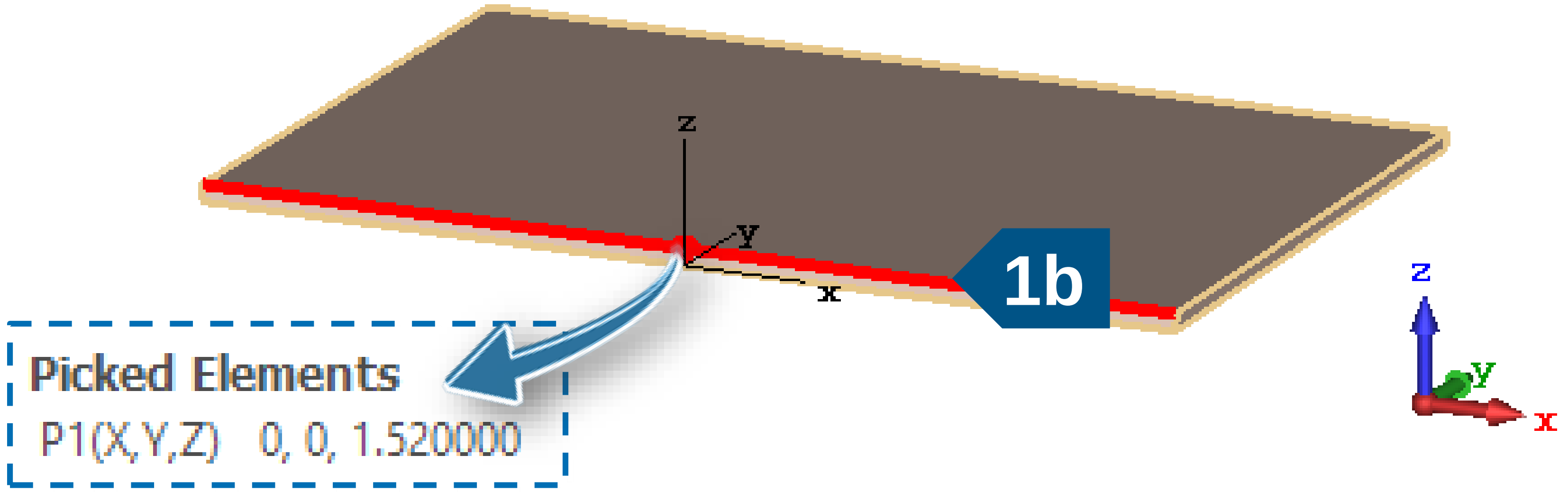




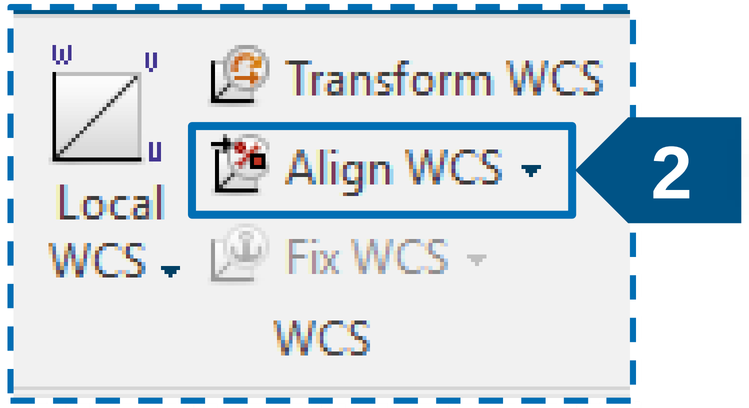
Model Feed and Patch (1/3)

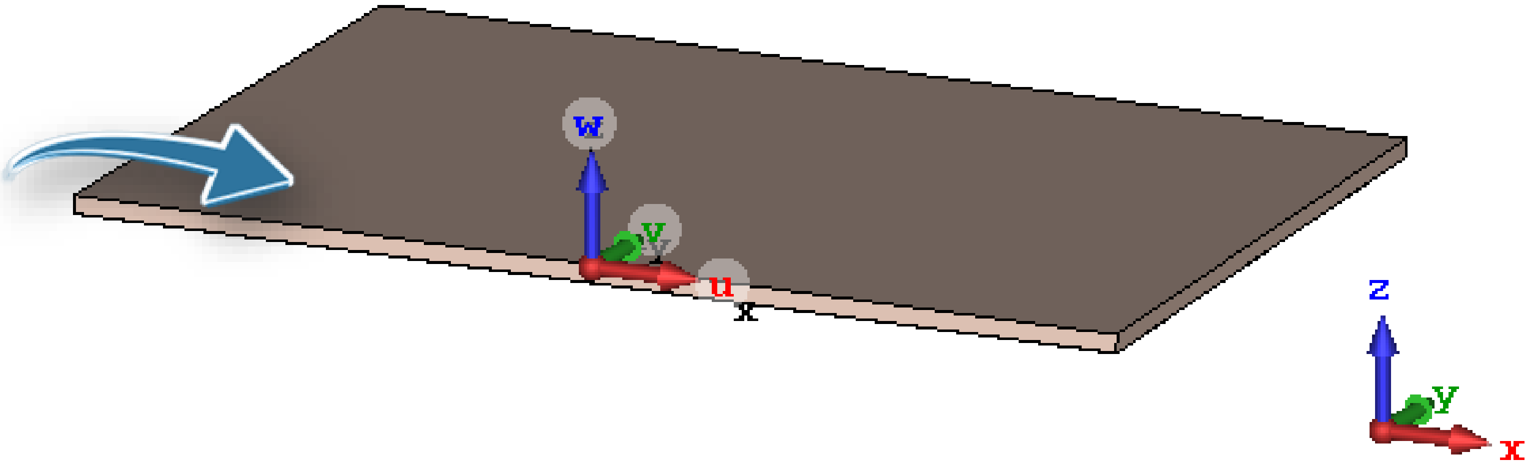
1. Open Pick Points Menu.
    a. Select **“Pick Edge Center” (m)**.
    b. Select top edge of the substrate. Check point coordinates.





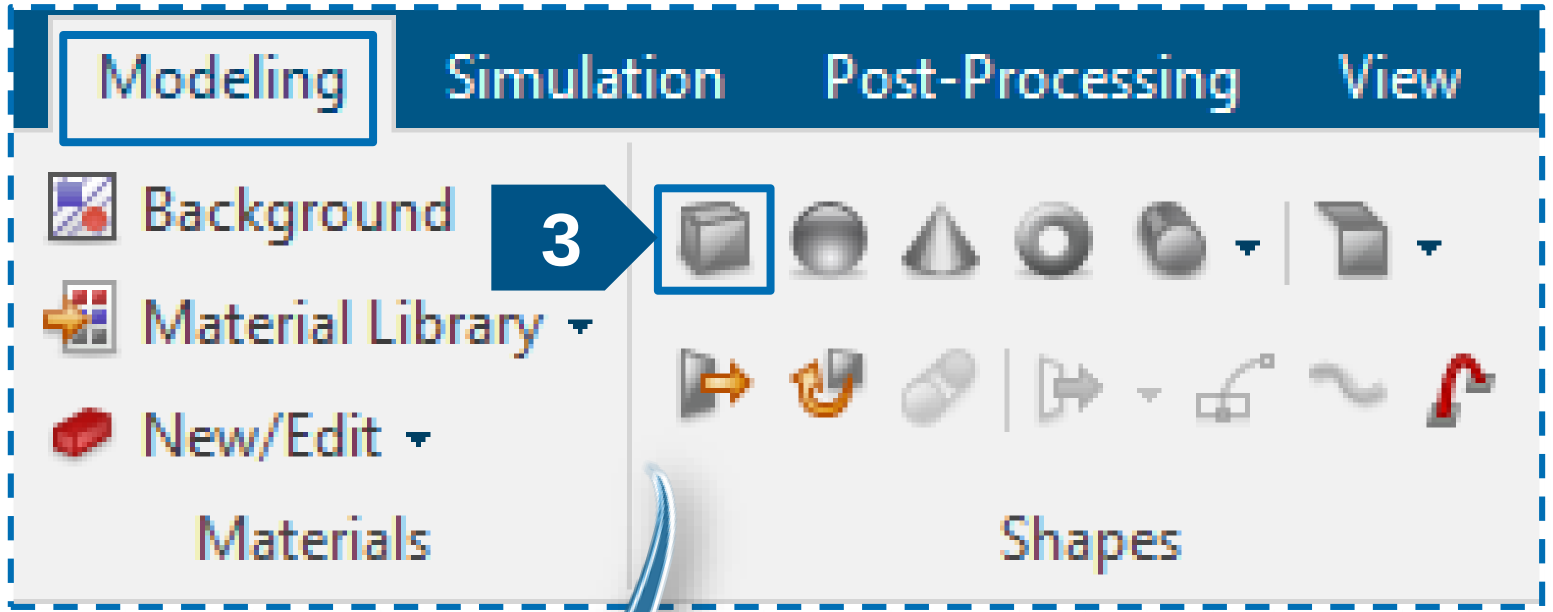
2. Align **WCS** with the selected edge (**w**).



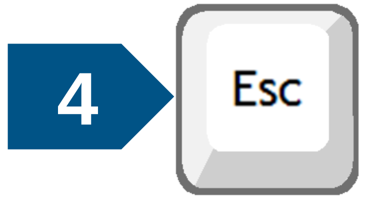


Model Feed and Patch (2/3)

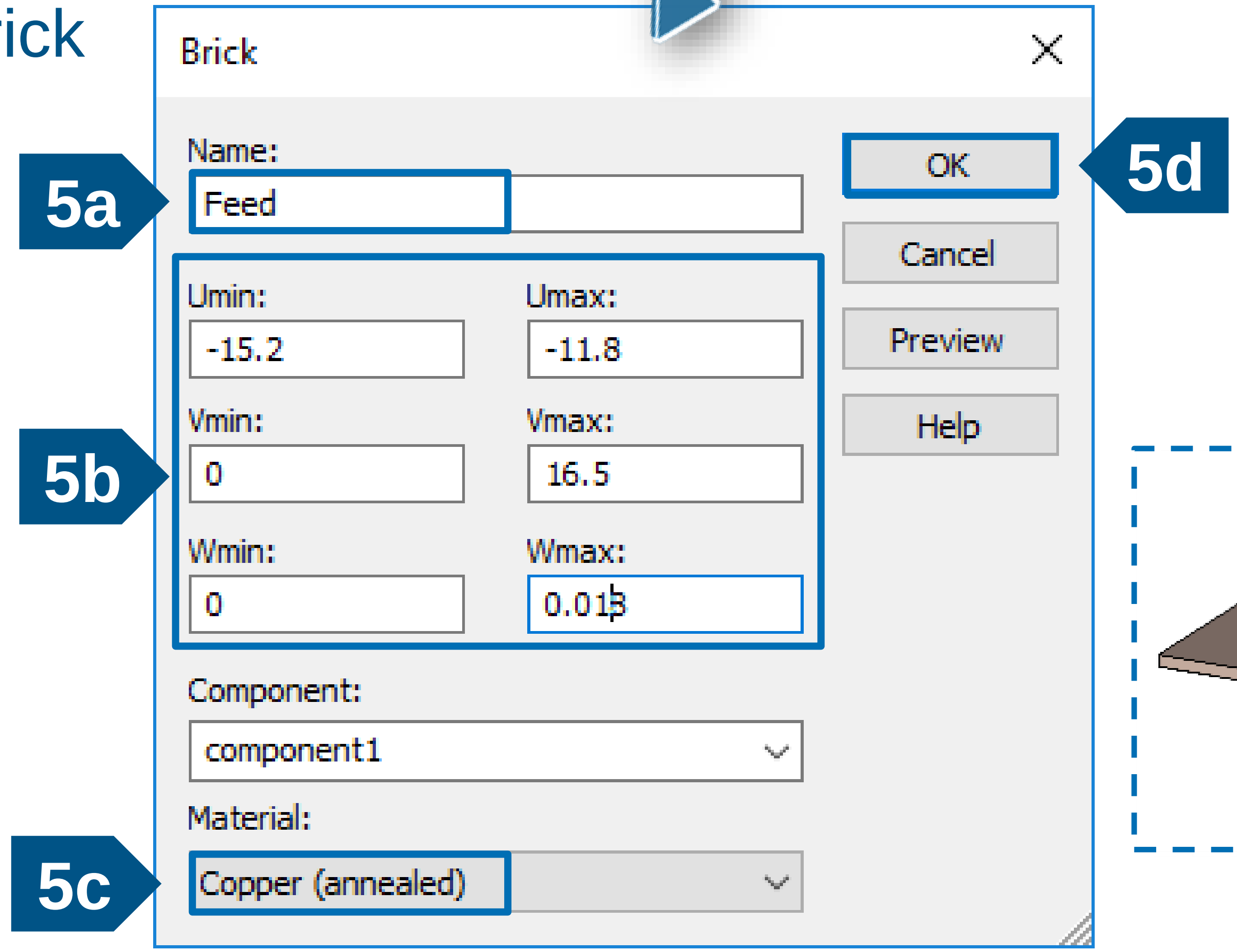
3. Select **Brick** in the Modeling Ribbon.

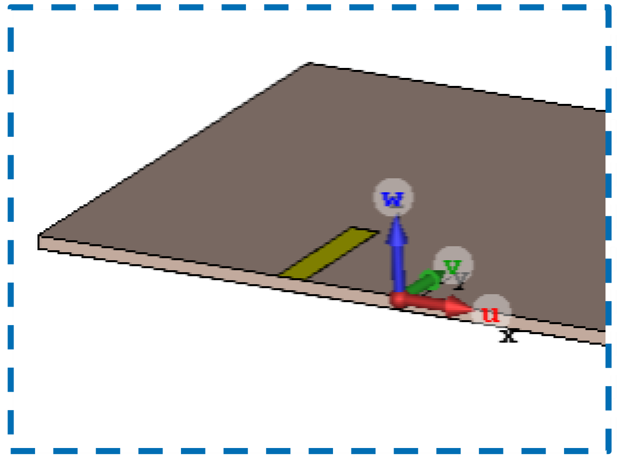


4. Click **ESC** on the keyboard to show the Brick dialog box.



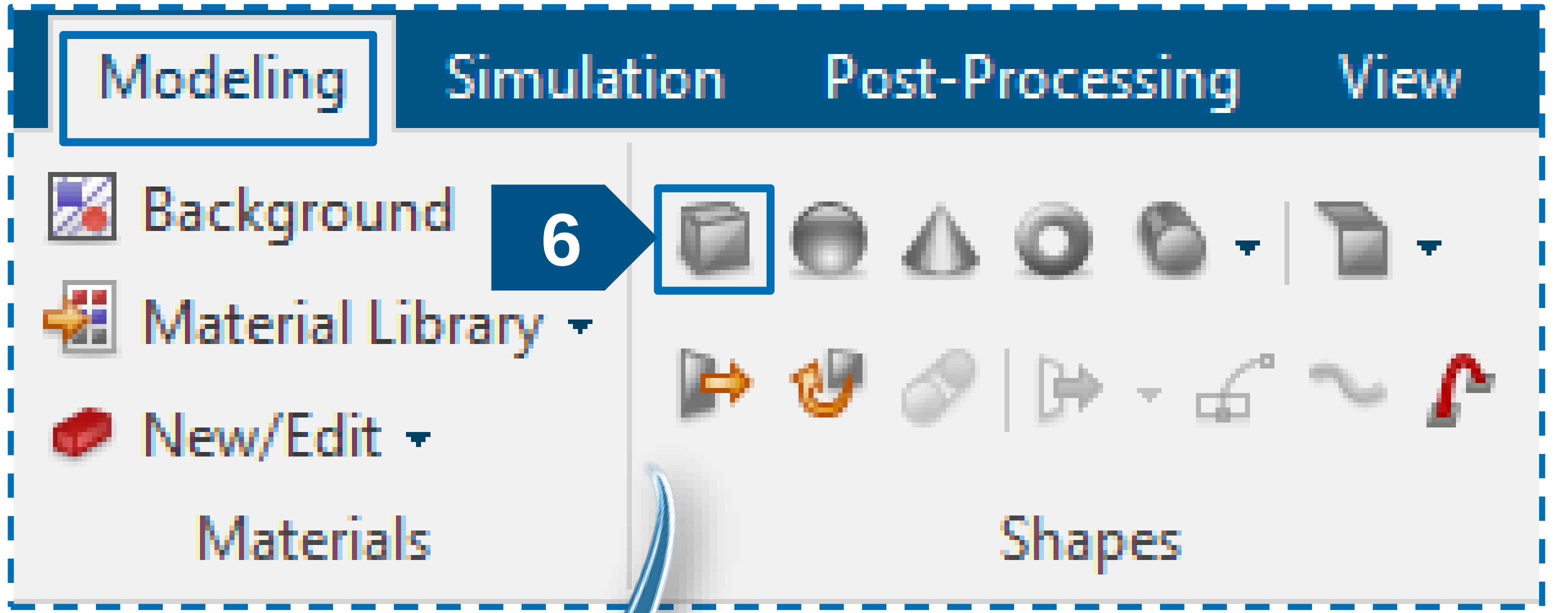
5. Define Brick properties.
   a. Name object as **"Feed"**.
   b. Set the Dimension of the feed.
   c. Set the material to **Copper**.
   d. Click OK to confirm.



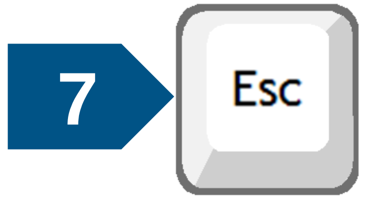


Model Feed and Patch (3/3)

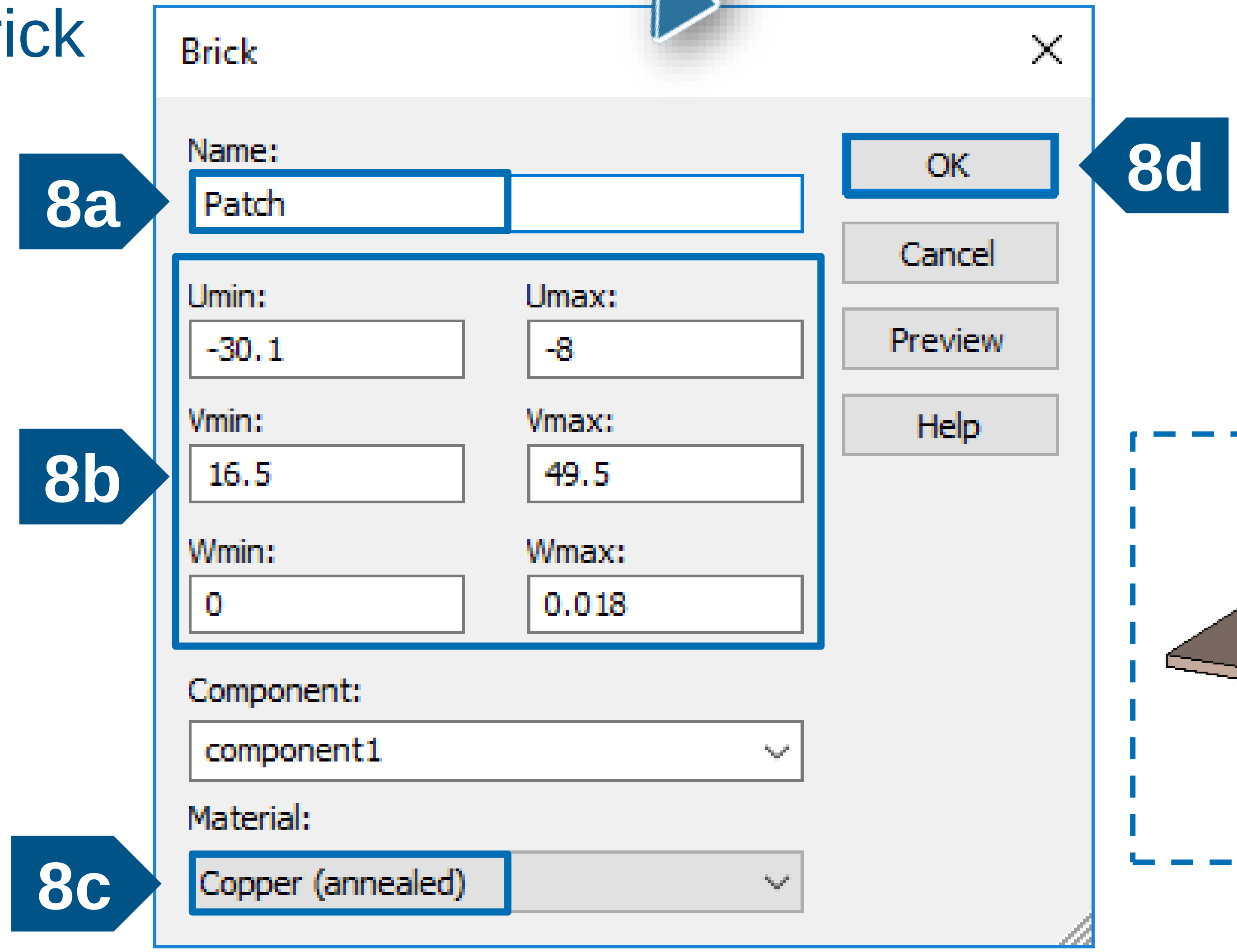
6. Select **Brick** in the Modeling Ribbon.

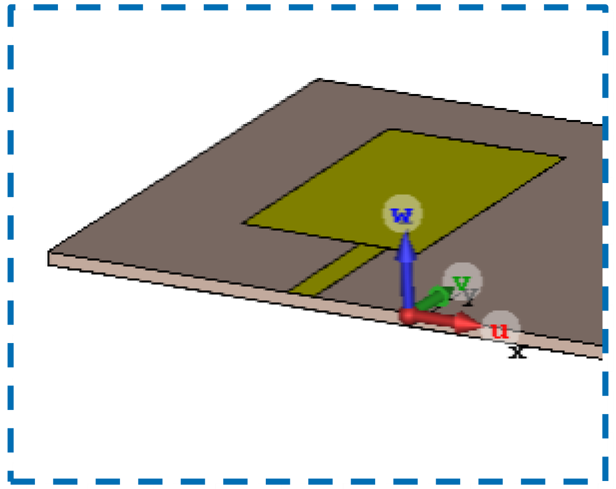


7. Click **ESC** on the keyboard to show the Brick dialog box.



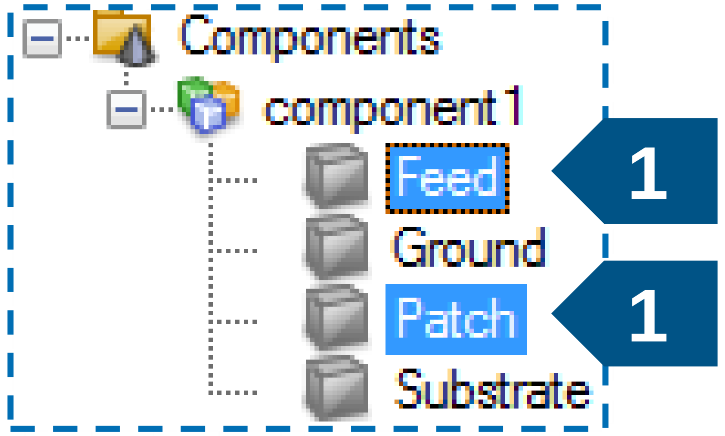
8. Define Brick properties.
    a. Name object as “**Patch**”.
    b. Set the Dimension of the patch.
    c. Set the material to **Copper**.
    d. Click OK to confirm.



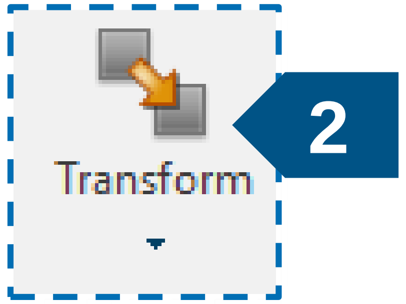


Mirror Feed and Patch

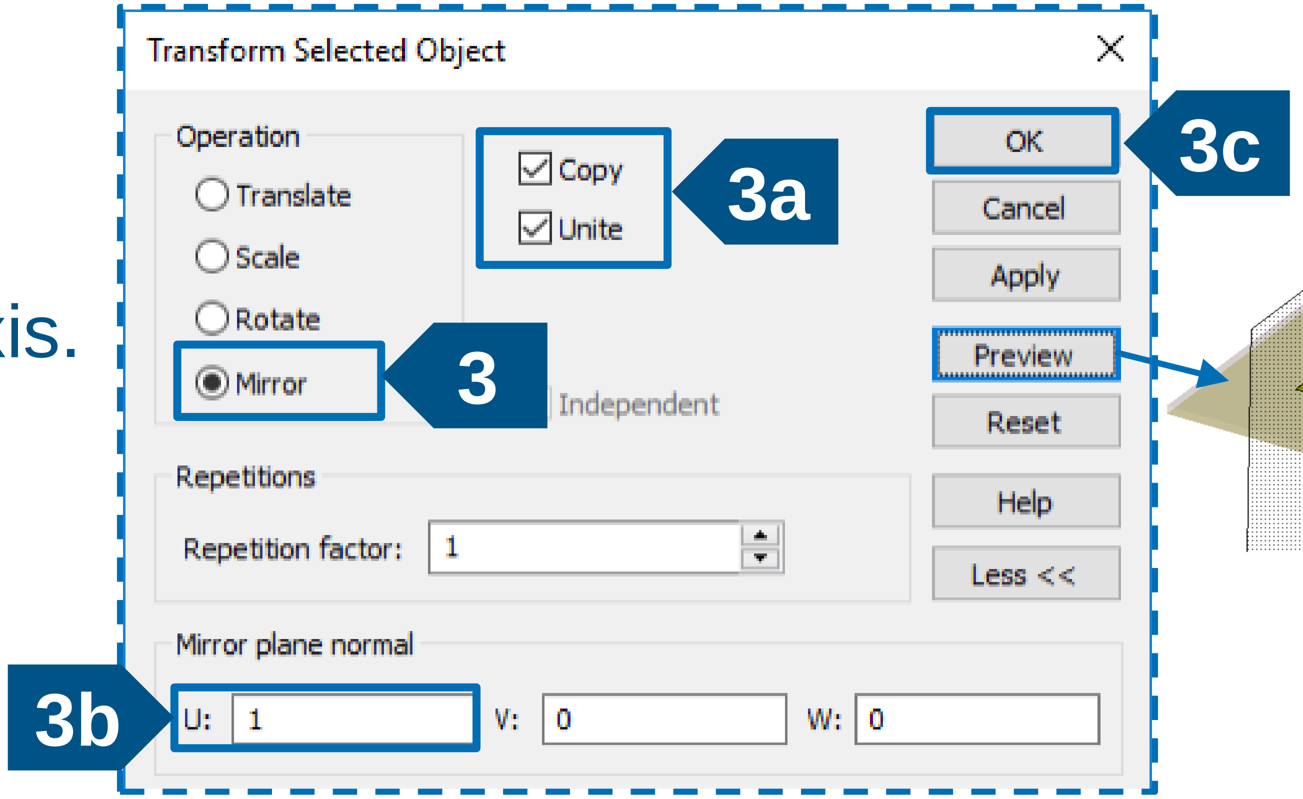
1. Select **Feed** & **Patch** from the Component Tree.

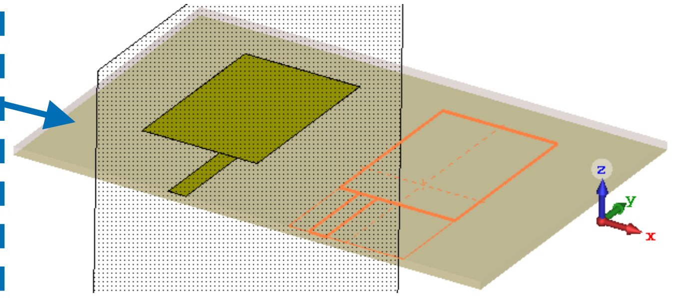


2. Select **Transform** from the Modeling Ribbon.

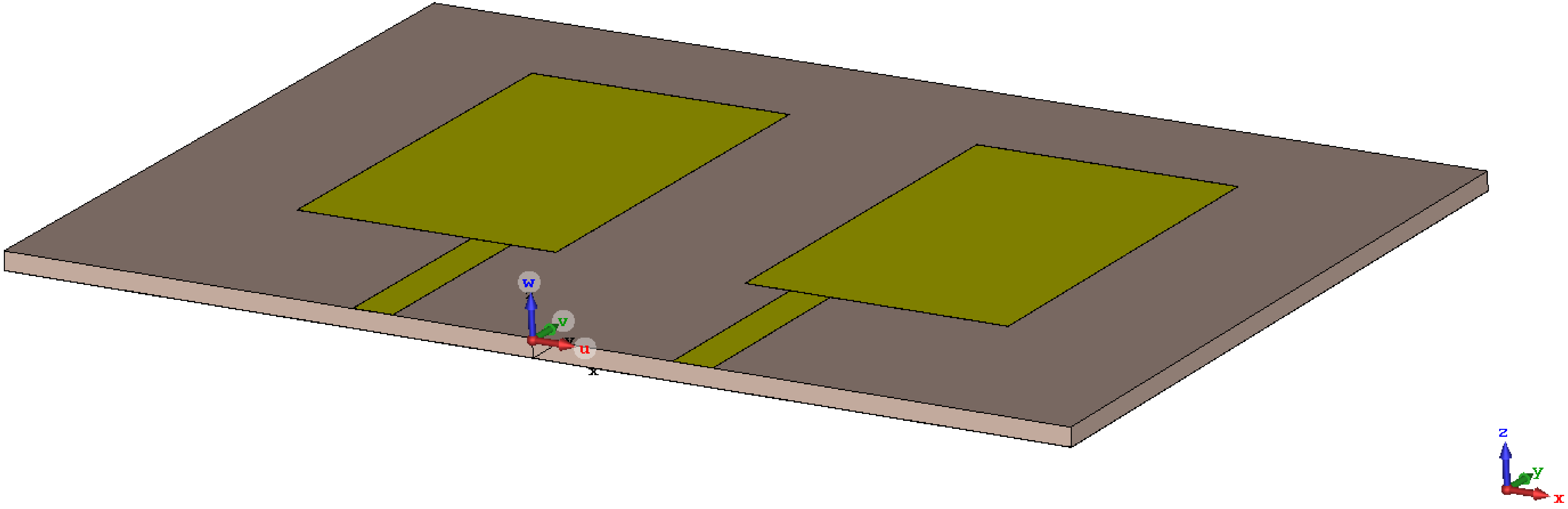


3. Apply **Mirror** operation.
   a. Enable Copy & Unite.
   b. Define Mirror plane normal along U axis.
   c. Click OK to proceed.



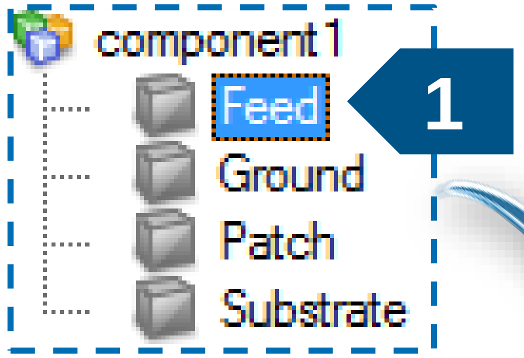


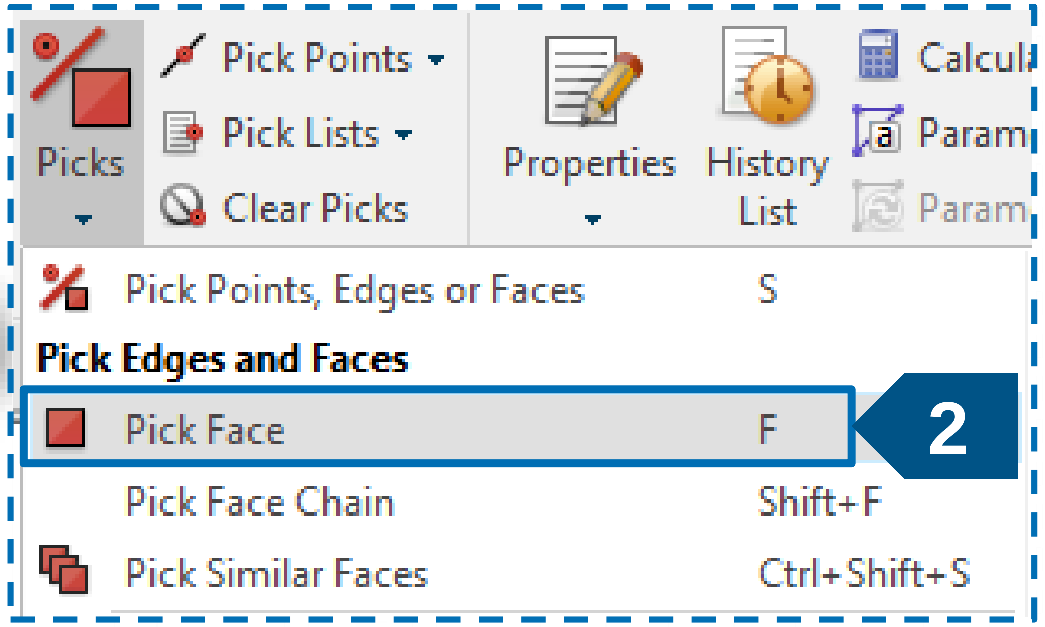
Dual Patch with Microstrip Feeding Network



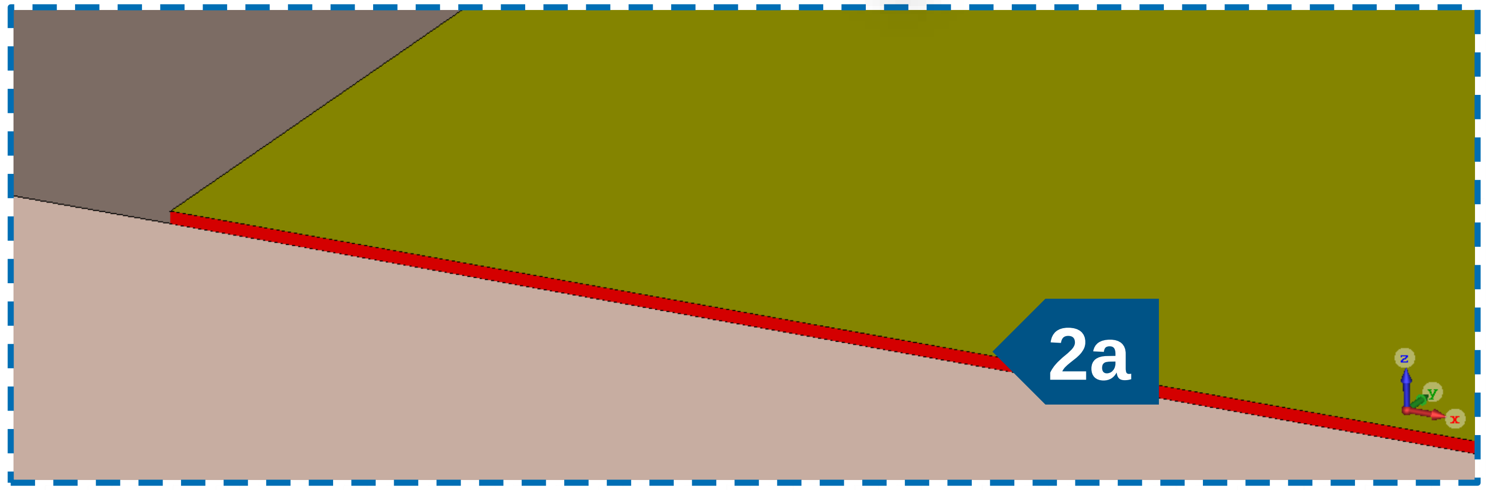
Define Excitation (1/3)

1. Select **Feed** from the Component Tree.



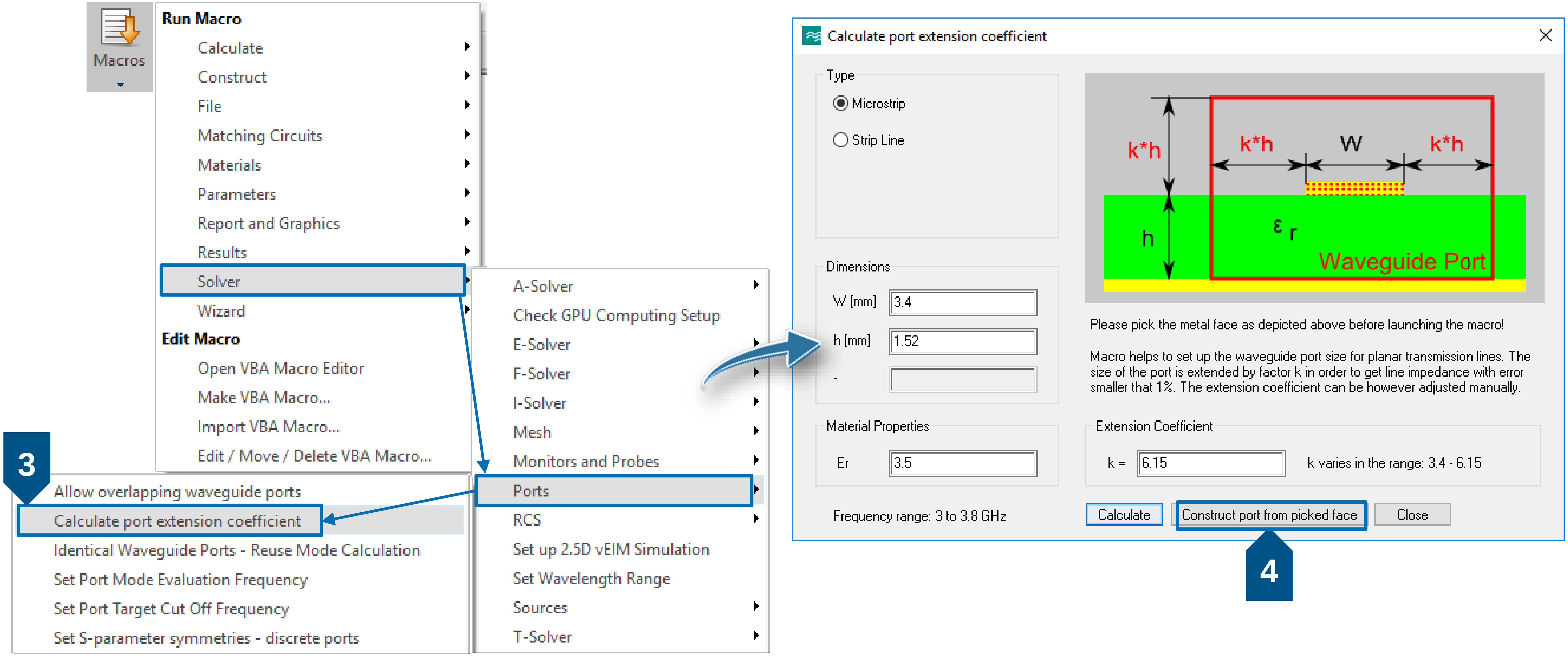


2. Enable **Pick Face (f)** from Picks Menu.
   a. Double click to select tiny face of the feed as shown in the picture below right.



Define Excitation (2/3)

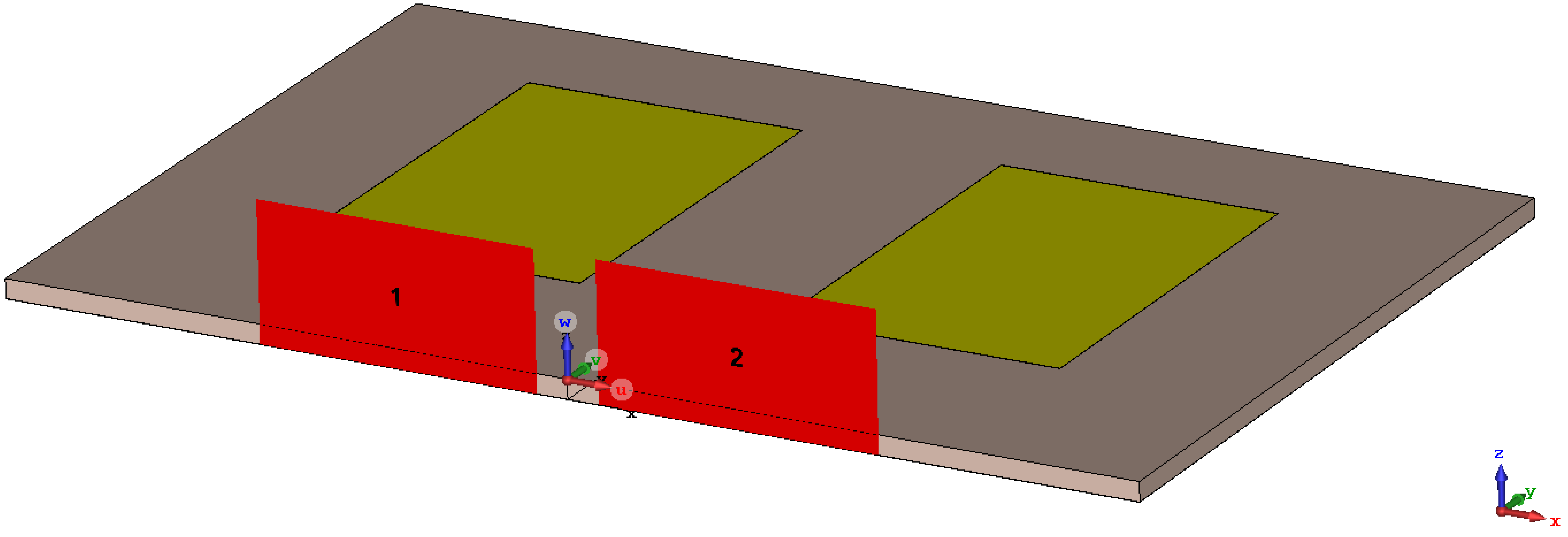
3. Use macro to specify **Waveguide Port extension**.
4. Construct Waveguide Port from Picked Face.



Define Excitation (3/3)

5. Repeat **Step 1 to Step 4** to construct the 2nd Waveguide Port associated to the 2nd feed.

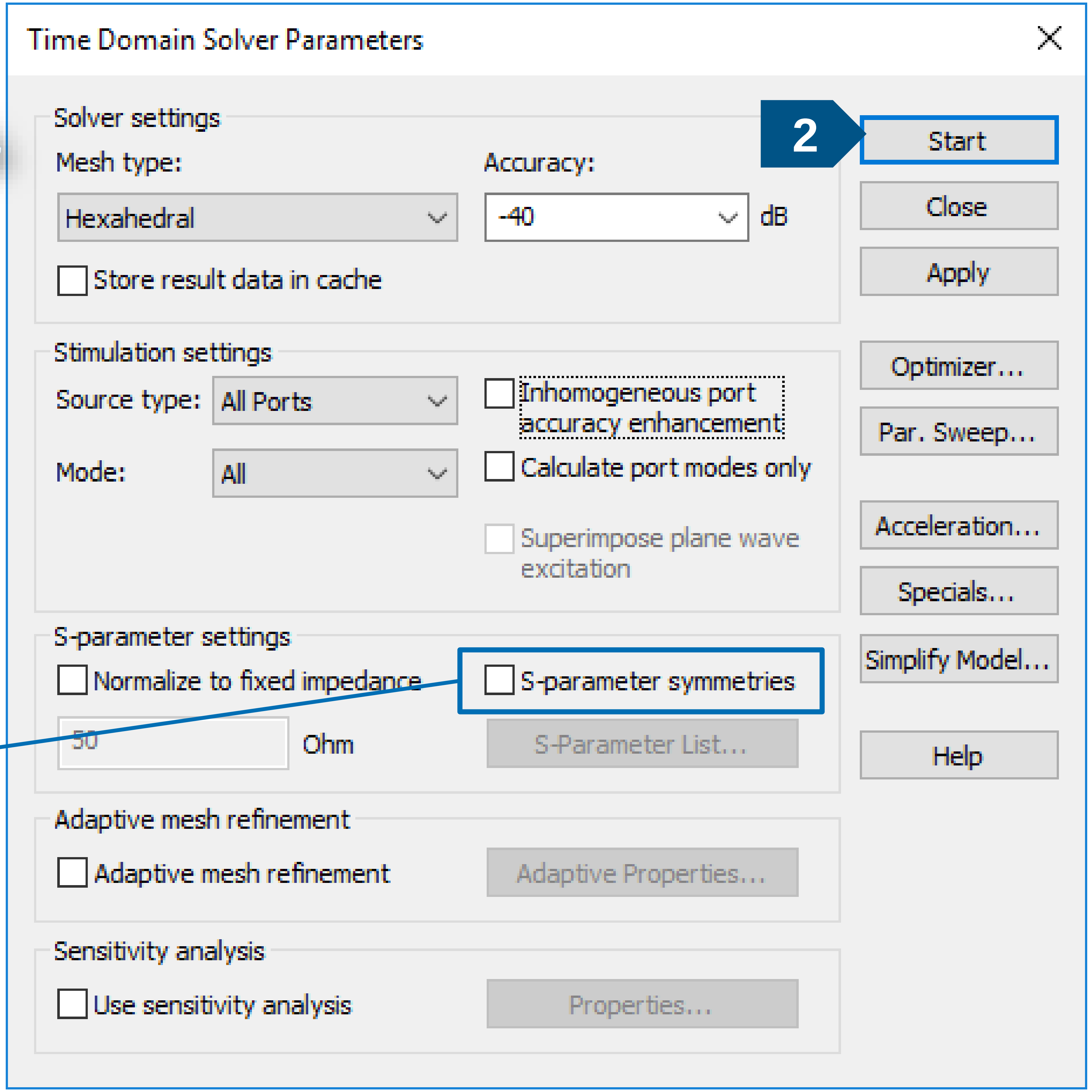
At the end the structure should look like the one in the below picture.



Transient Solver Simulation

1. Open Time Domain Solver.

2. Start Simulation.

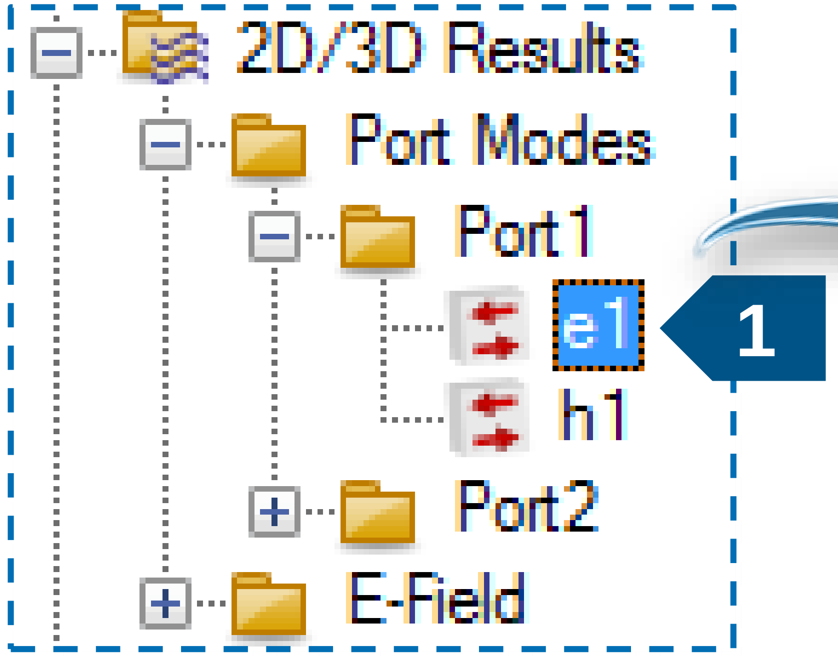


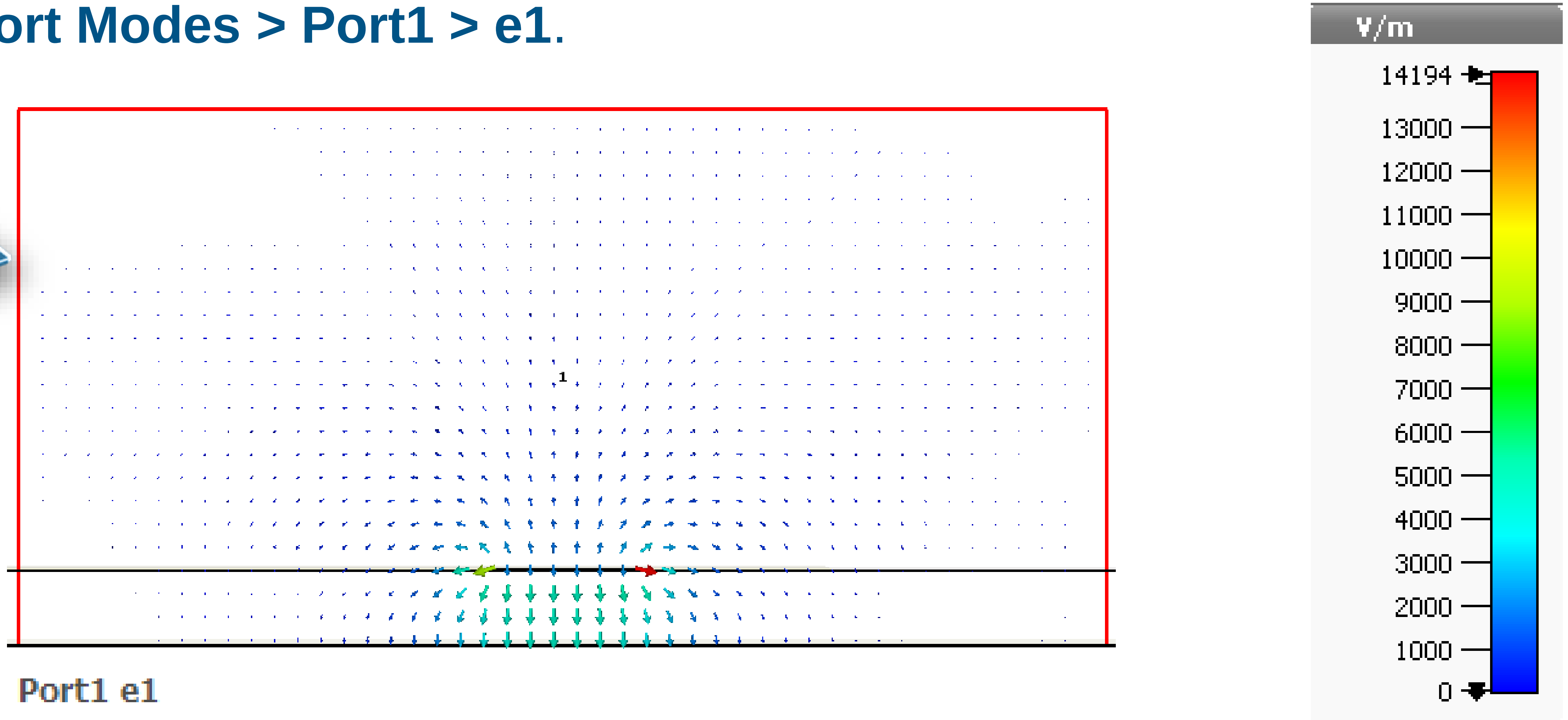
If you are interested only in the S-Matrix calculation setup the S-Parameter symmetries to speed-up the simulation process. Only one port will be calculated.

View Port Modes

The first operation performed in the simulation is the resolution of the 2D Eigenmode Solver problem of all waveguide ports defined in the project.

1. Select **2D/3D Results > Port Modes > Port1 > e1**.



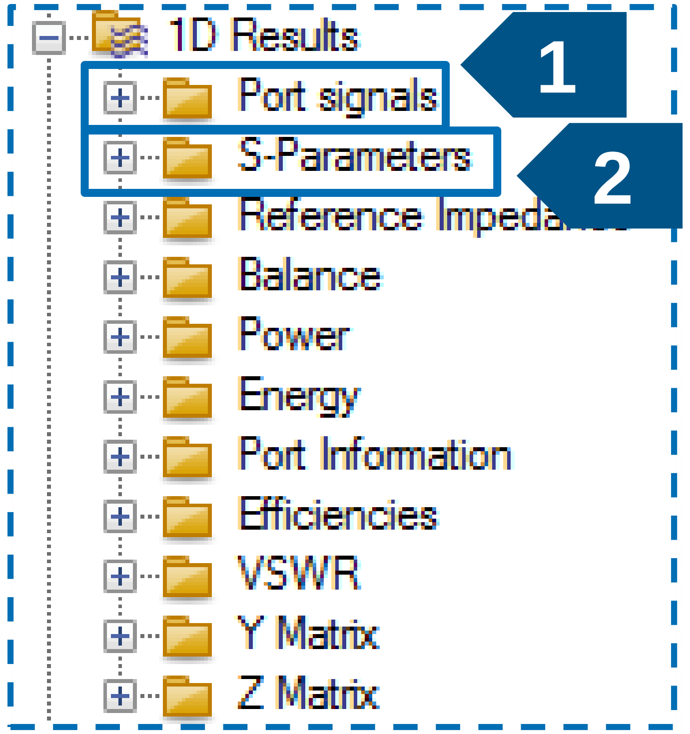


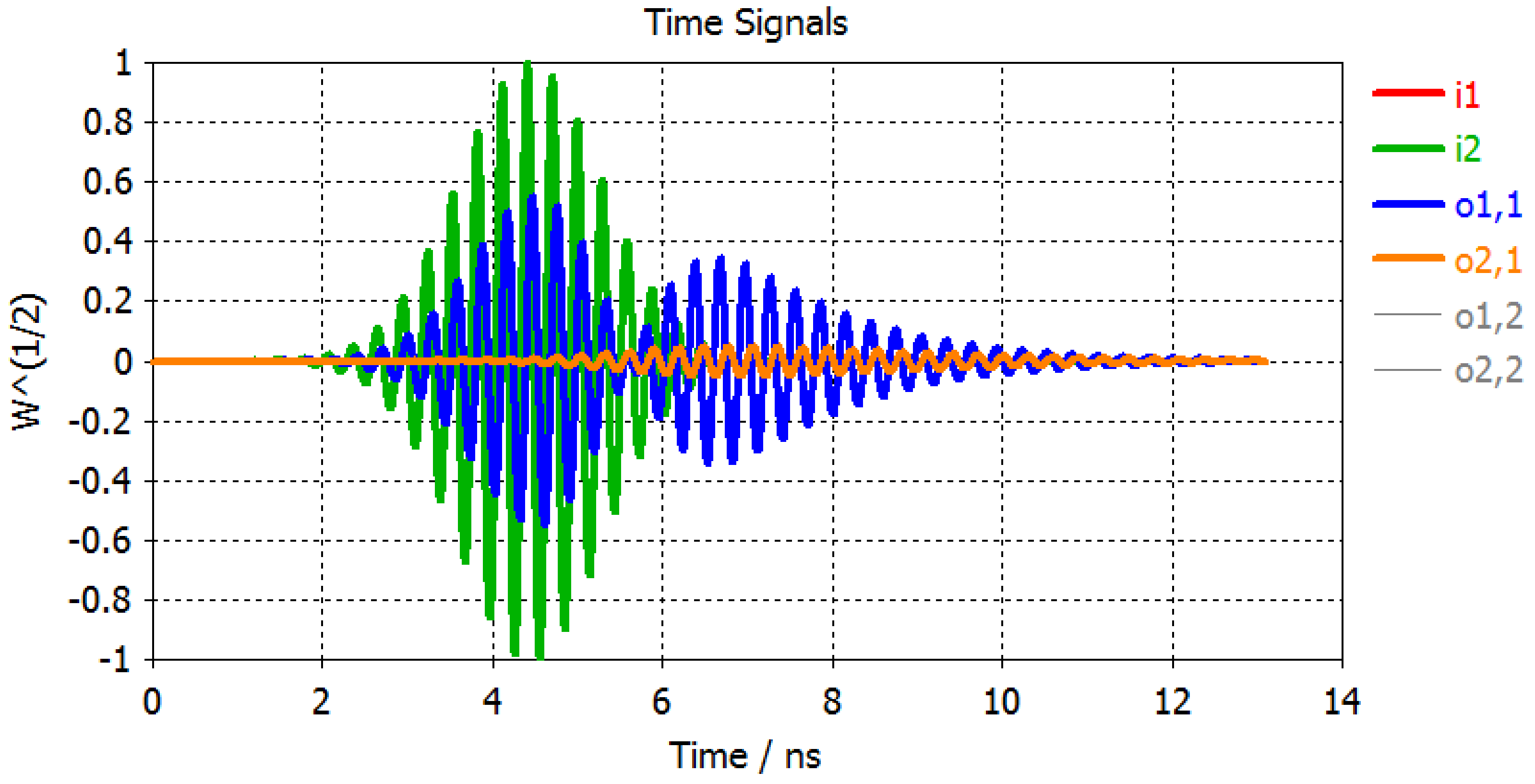
Port1 e1

Frequency	3.4 GHz
Phase	0
Mode type	Quasi TEM
Line Imp.	48.8434 Ohm
Wave Imp.	272.461 Ohm
Beta	118.54 1/m
Accuracy	9.10677e-11
Maximum	14194.4 V/m

Check **Mode Type** and **Line Impedance** value in order to be sure you are exciting the microstrip in the correct way.

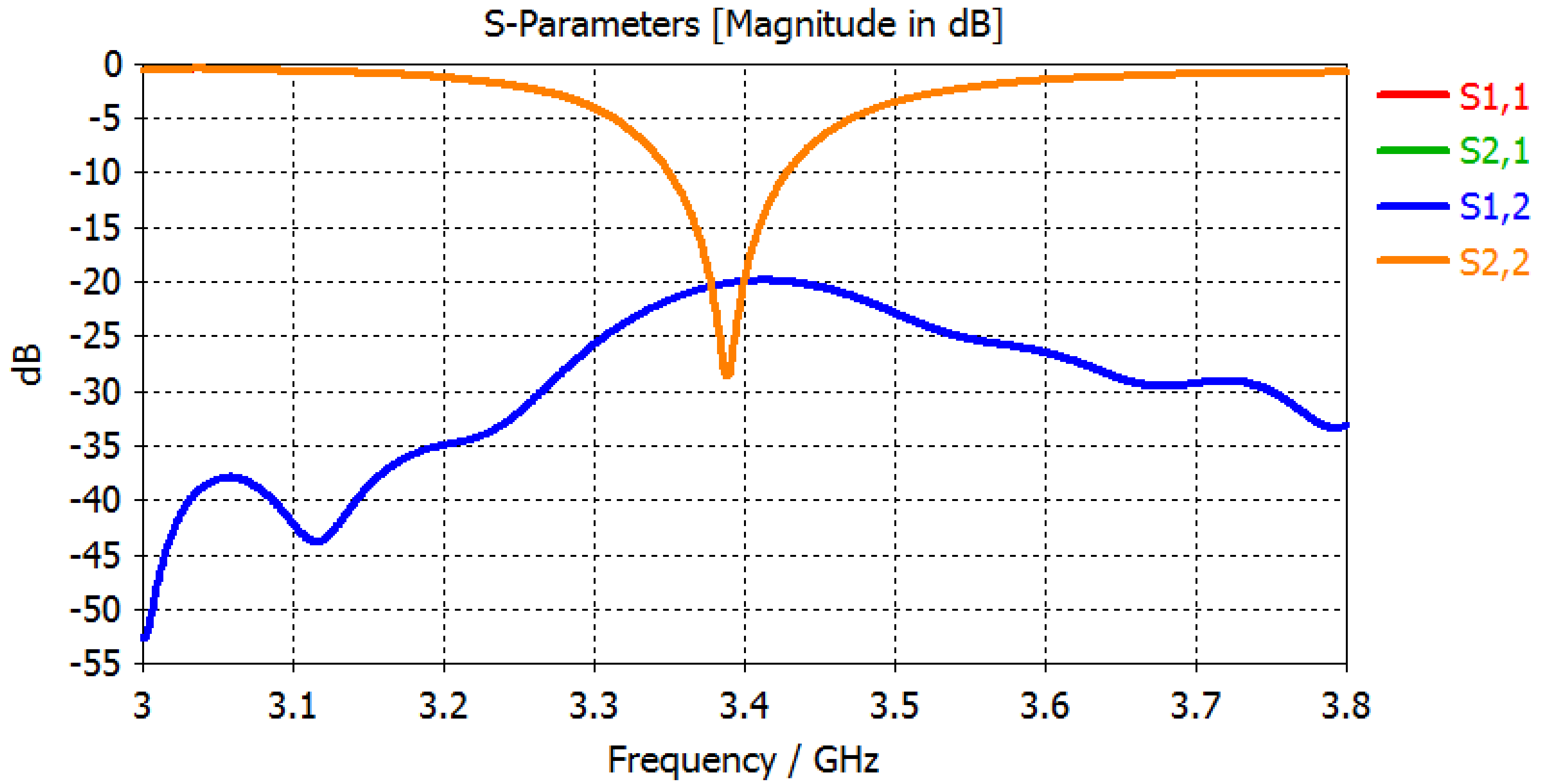
View 1D Results (1/2)





1. Select **Port signals** folder.

The signals (o1,1 & o2,1) are oscillating and slowly decaying to zero → The antenna is resonant.

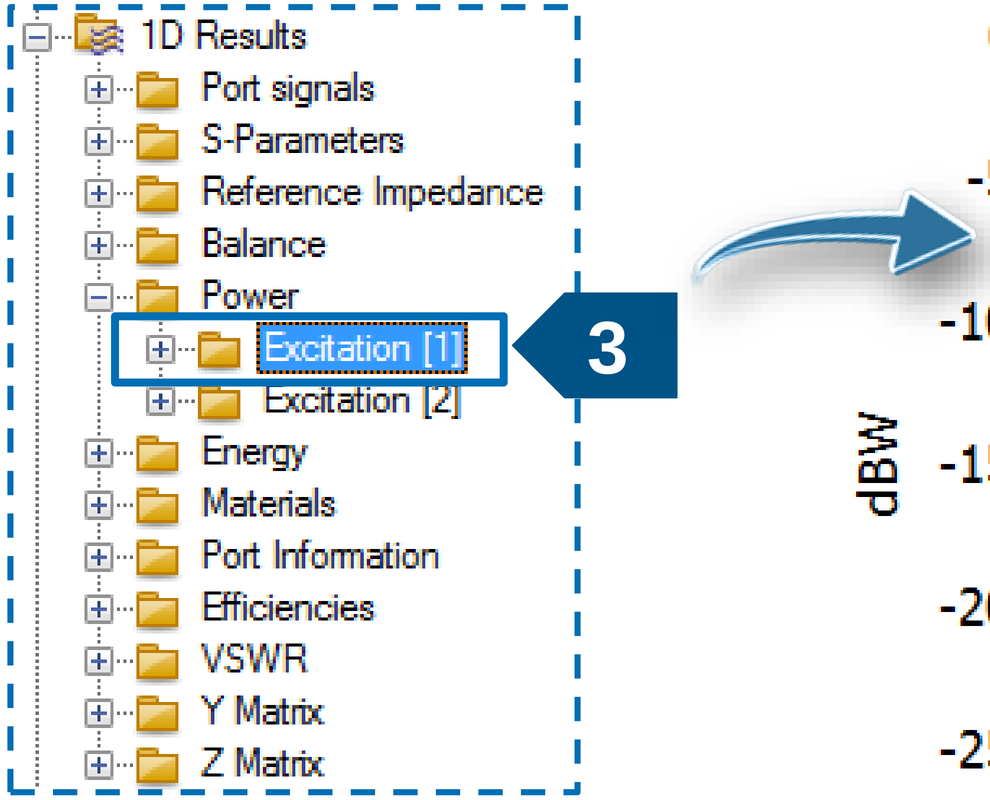


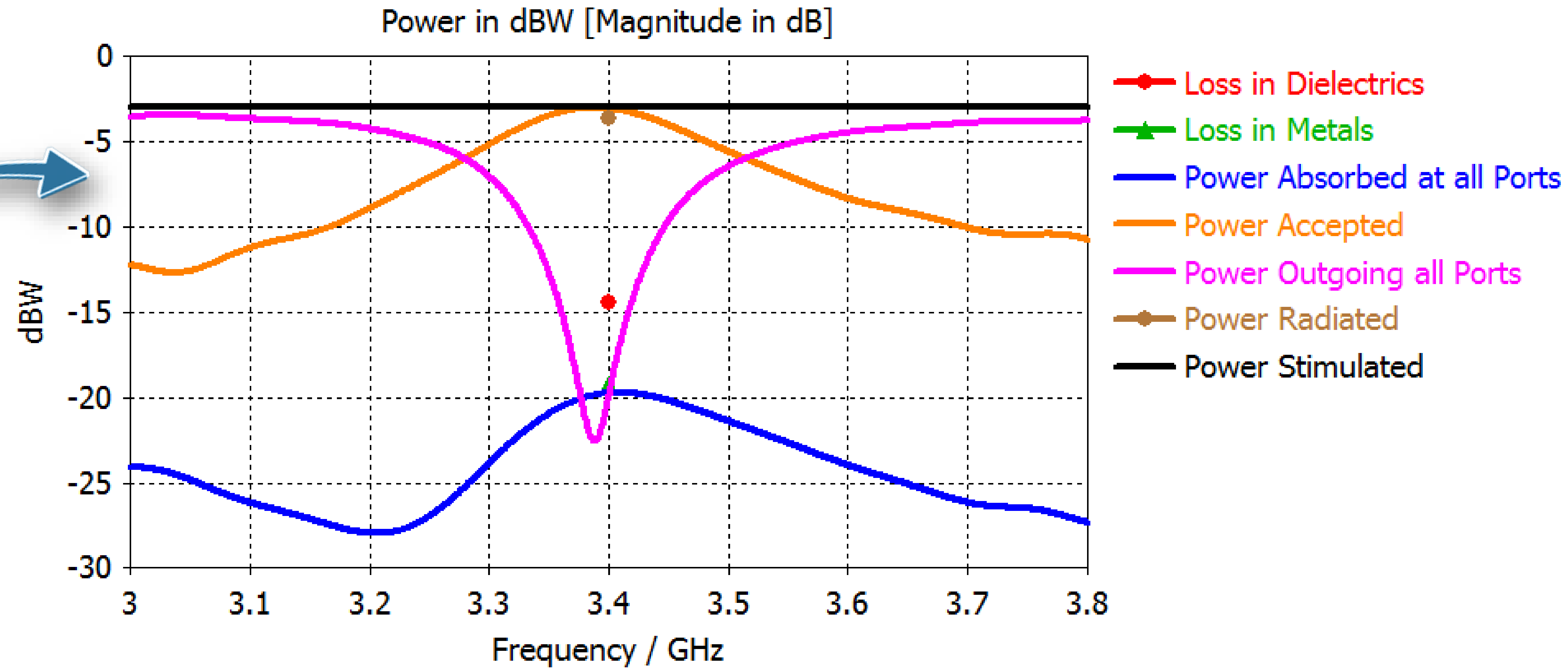
2. Select **S-Parameters** folder.

The patches are matched around 3.4 GHz and are strongly coupled between each other (-20 dB)

View 1D Results (2/2)

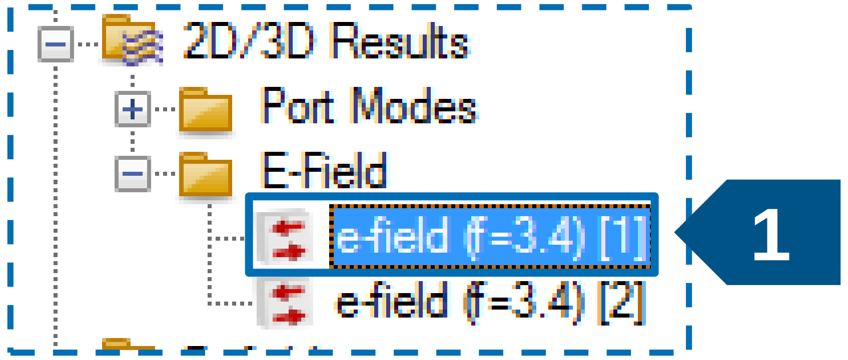
3. Select **Power > Excitation [1]** folder.

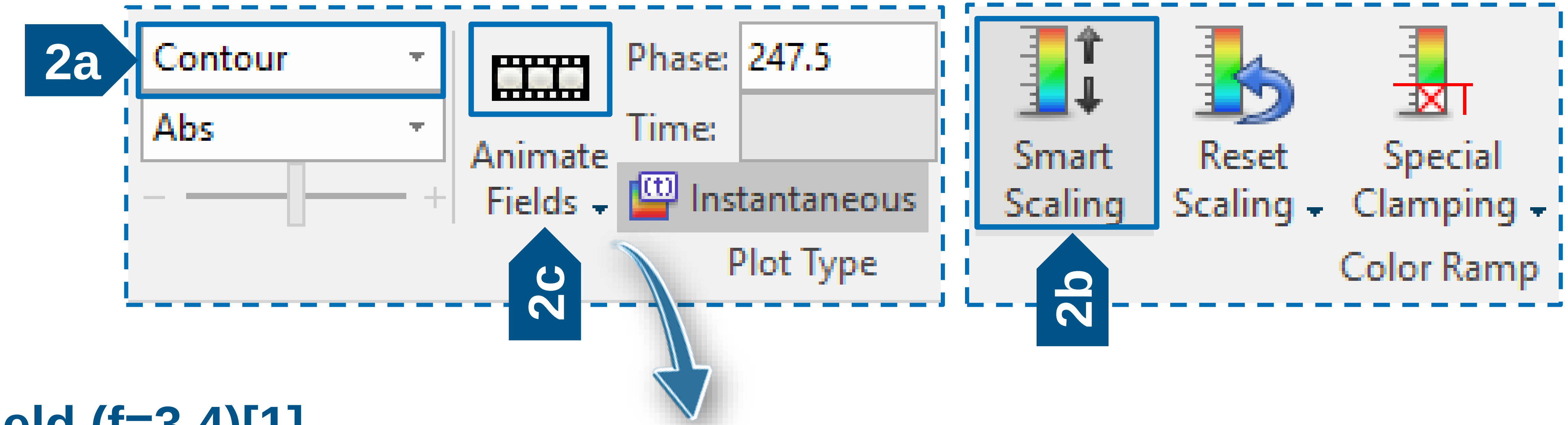




@ 3.4 GHz. Most of the Accepter Power (= $Pstim{\cdot}(1\text{-}|S11|^2\text{-}|S21|^2)$ is radiated away from the patch antenna. A small portion is lost in the Dielectrics (Taconic) and in the Metals (Copper).

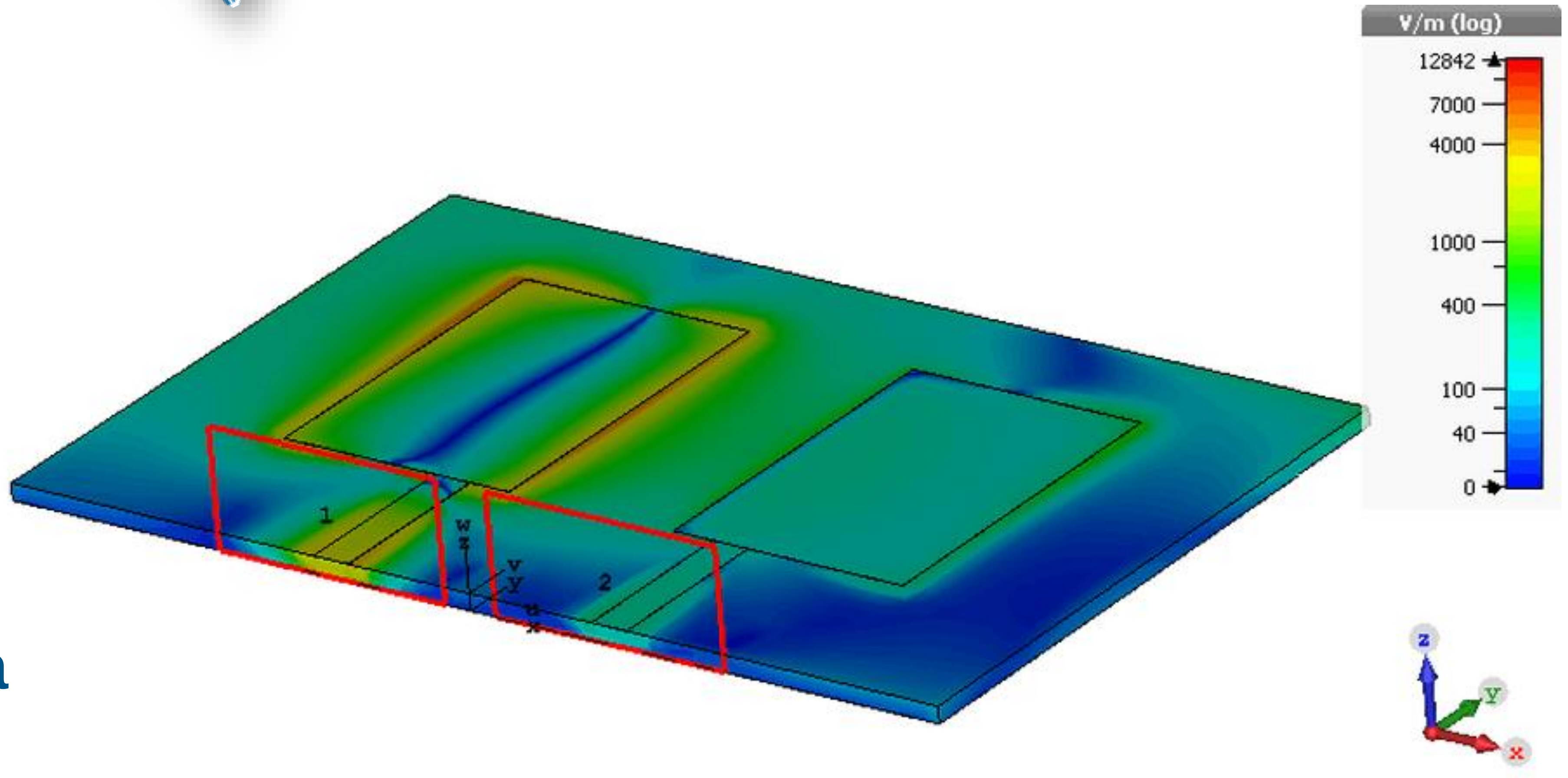
View 2D/3D Results





1. Select **E-Field > e-field (f=3.4)[1]**.

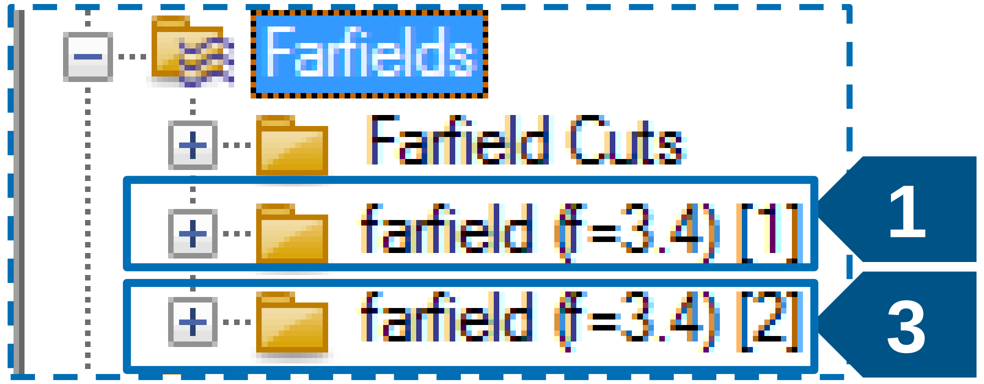
2. Specify field plot settings.
   a. Set Contour plot.
   b. Apply Smart Scaling.
   c. Animate Fields.

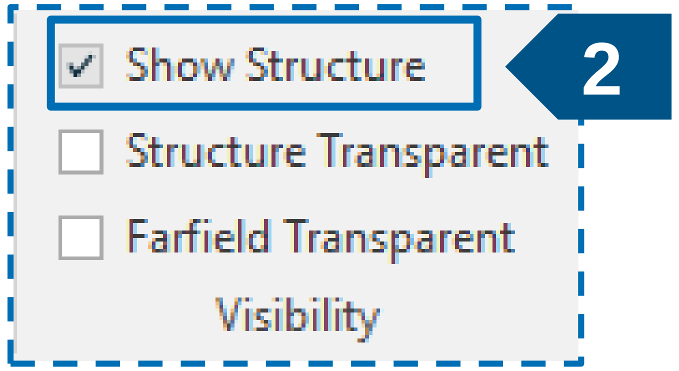


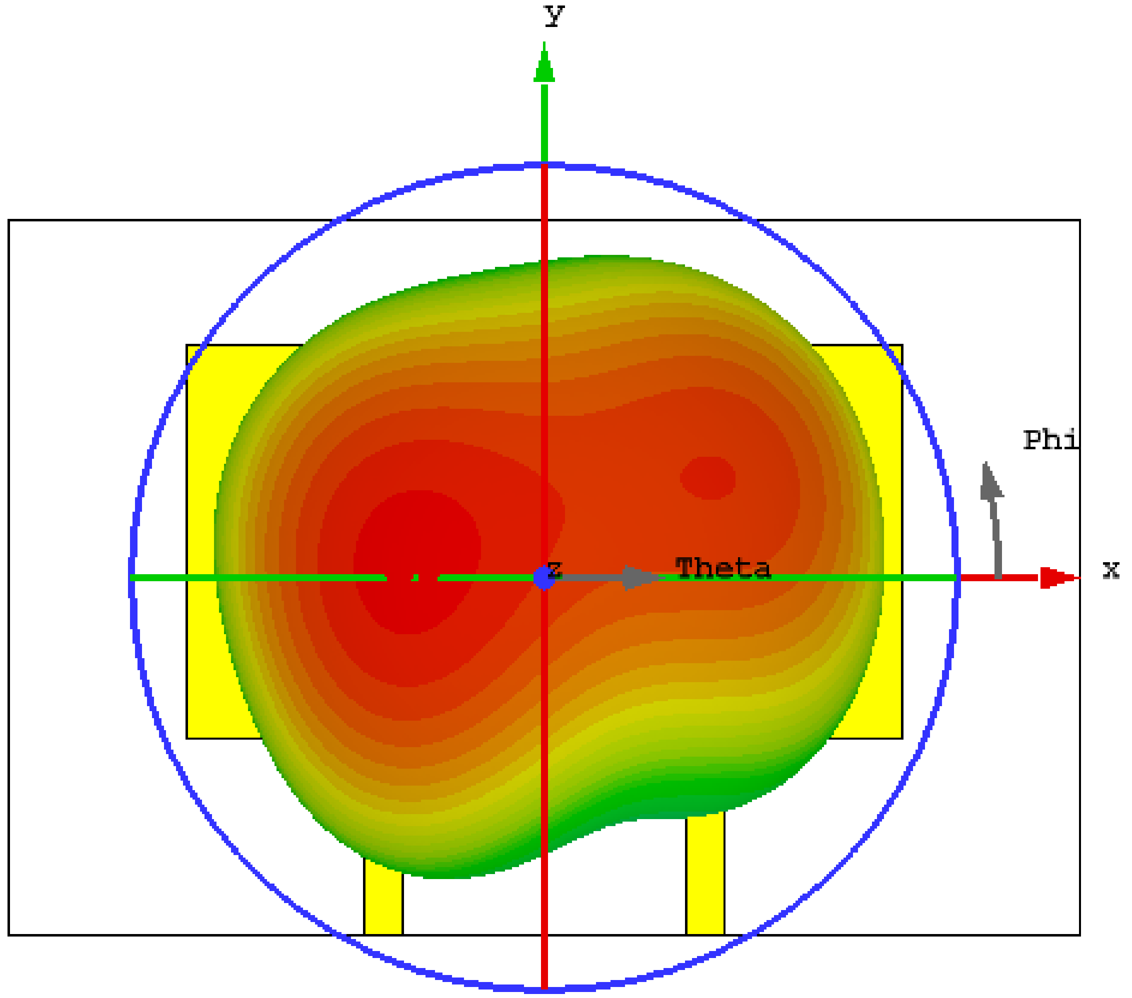
Only Port 1 is excited. Port 2 is closed on a matched load (48 Ohm).

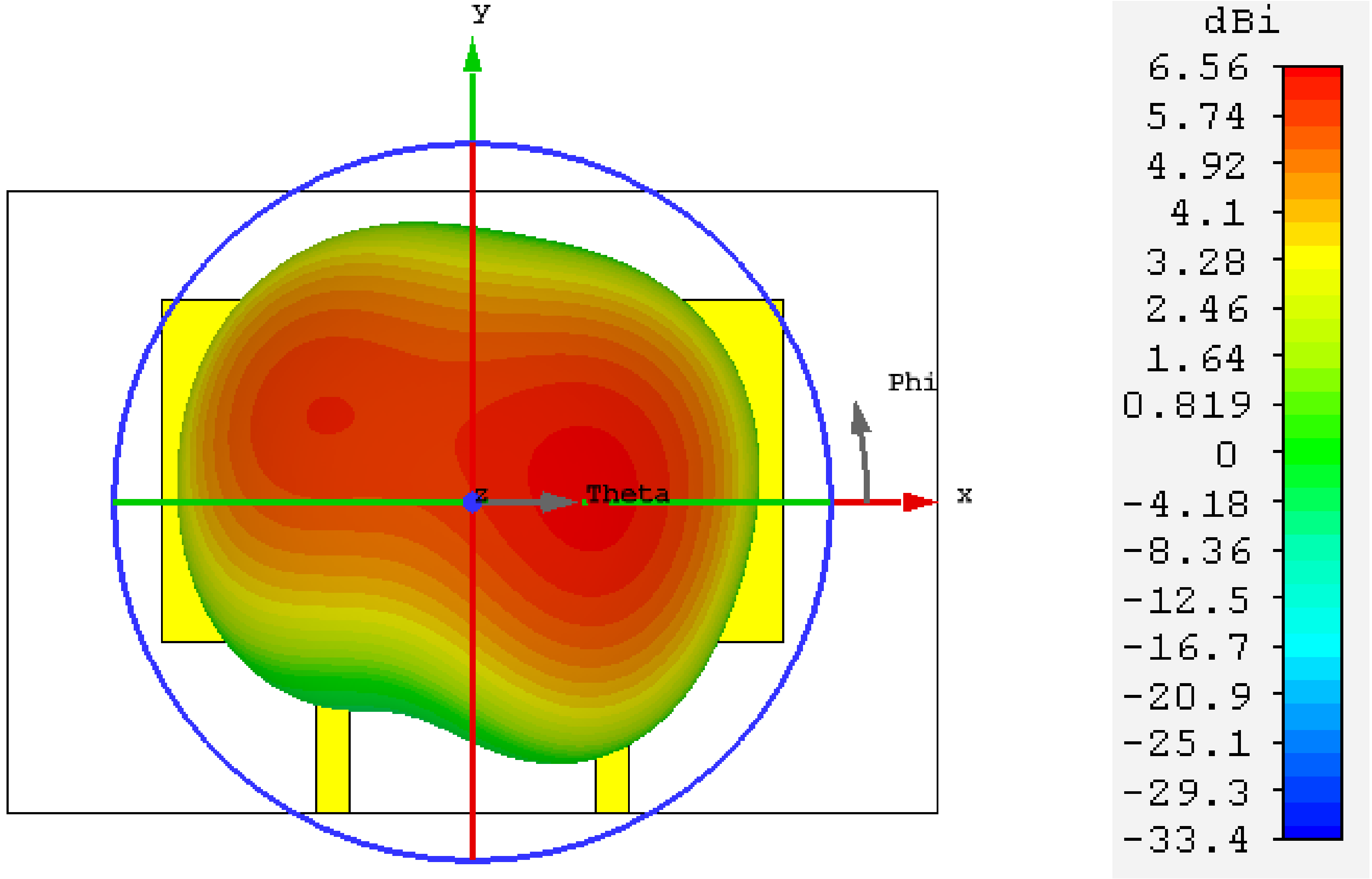
View Farfield Results

1. Select **Farfields > farfield (f=3.4)[1]**.
2. Enable "**Show Structure**" in the farfield ribbon to overlay the geometry on to the farfield plot.
3. Select **Farfields > farfield (f=3.4)[2]**.





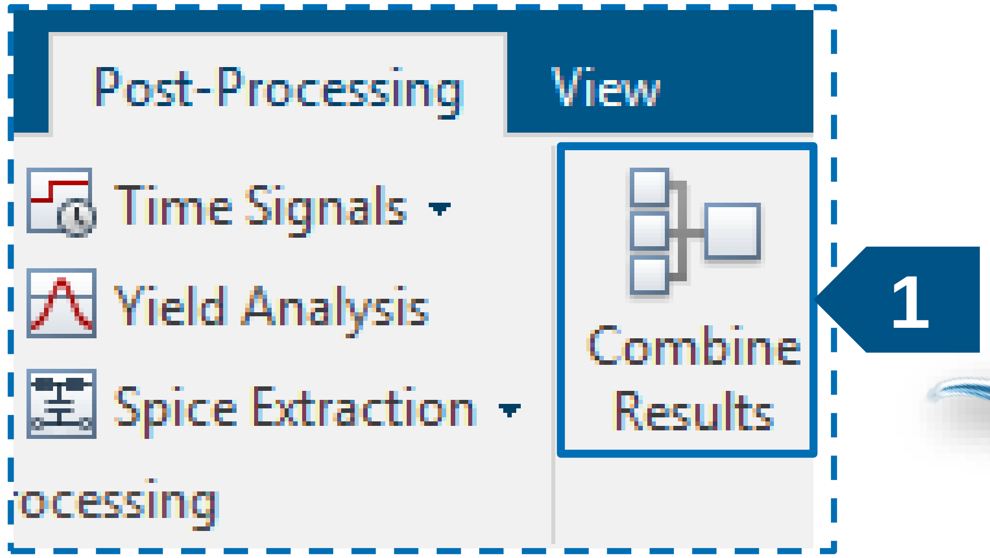


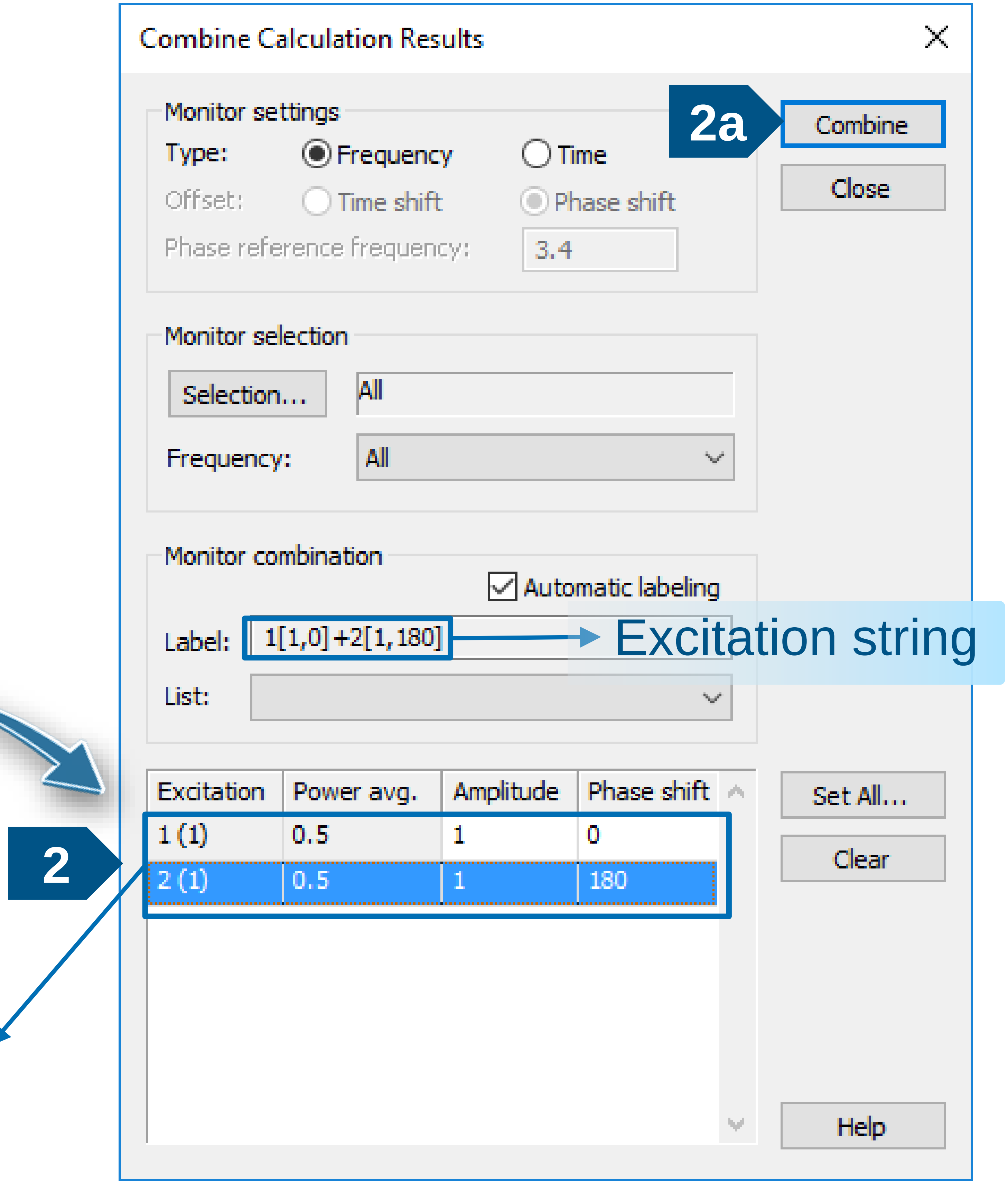


The farfield obtained exciting port [1] is mirrored (plane normal: x) respect to the farfield [2].

Combine Results (1/4)

1. Open **Combine Results** from the Postprocessing Ribbon to apply the superposition principle (**Linear system**).
2. Specify Amplitude & Phase of each port.
   a. Apply the **Combine**.



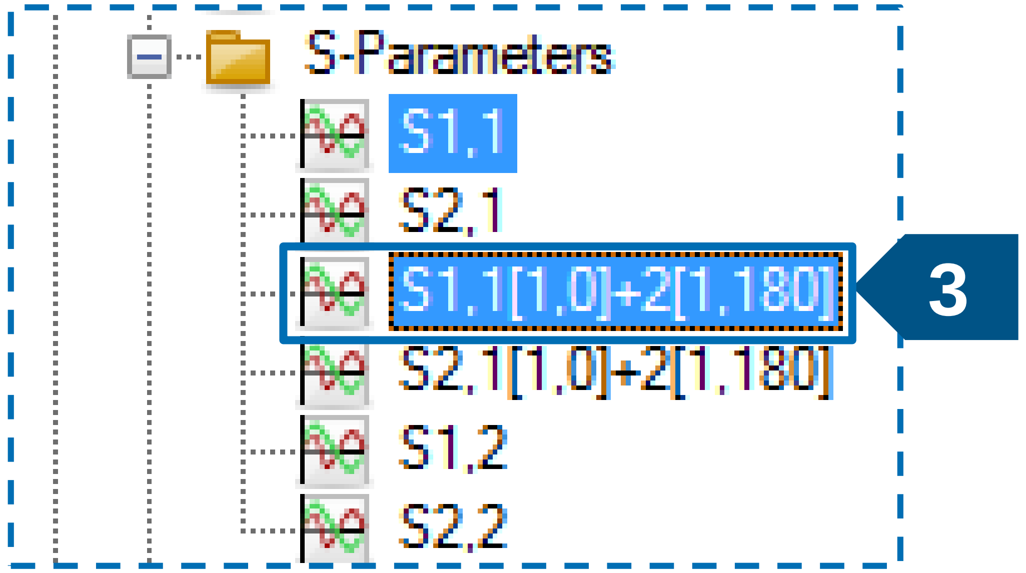


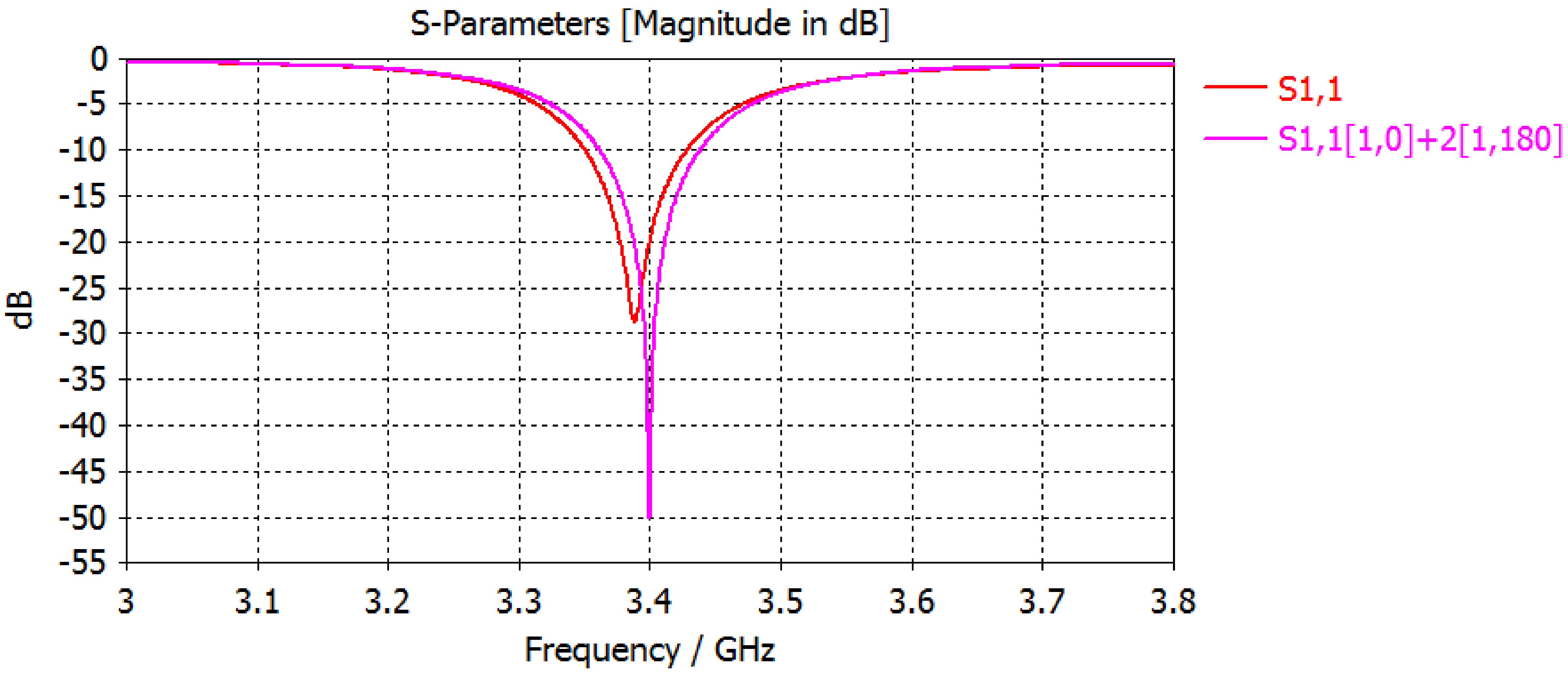
This operation mimics a simultaneous excitation of the patches with the same Power (0.5 W avg) and a **broadband Phase shift** (180°) in order to get constructive interference.

Combine Results (2/4)

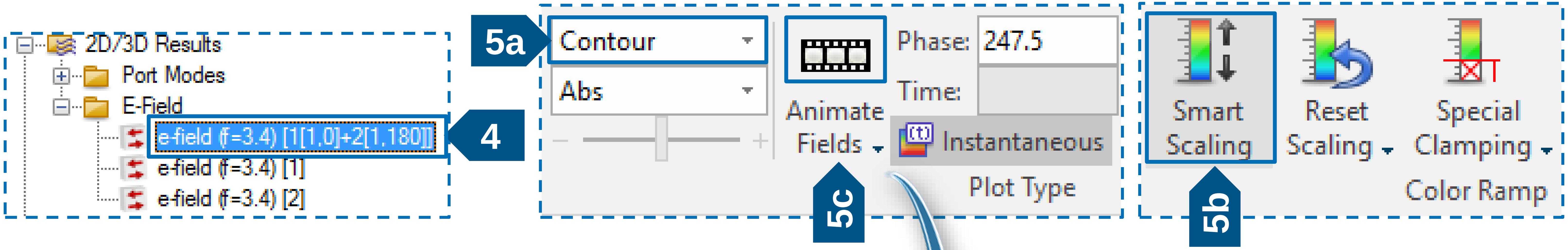
Under **1D Results, 2D/3D Results & Farfield** new entries will be automatically created with the excitation string **1[1,0]+2[1,180].**

3. Select new entry in the S-Parameters folder. In contrast to **standard S-Parameters** (S1,1), → *the ratio of incident and reflected voltage wave spectra at a port, where only one port is excited and all others are perfectly matched*, we have an **active S-Parameters** → *the reflected spectra of all excited ports are normalized to their own incident spectra.*



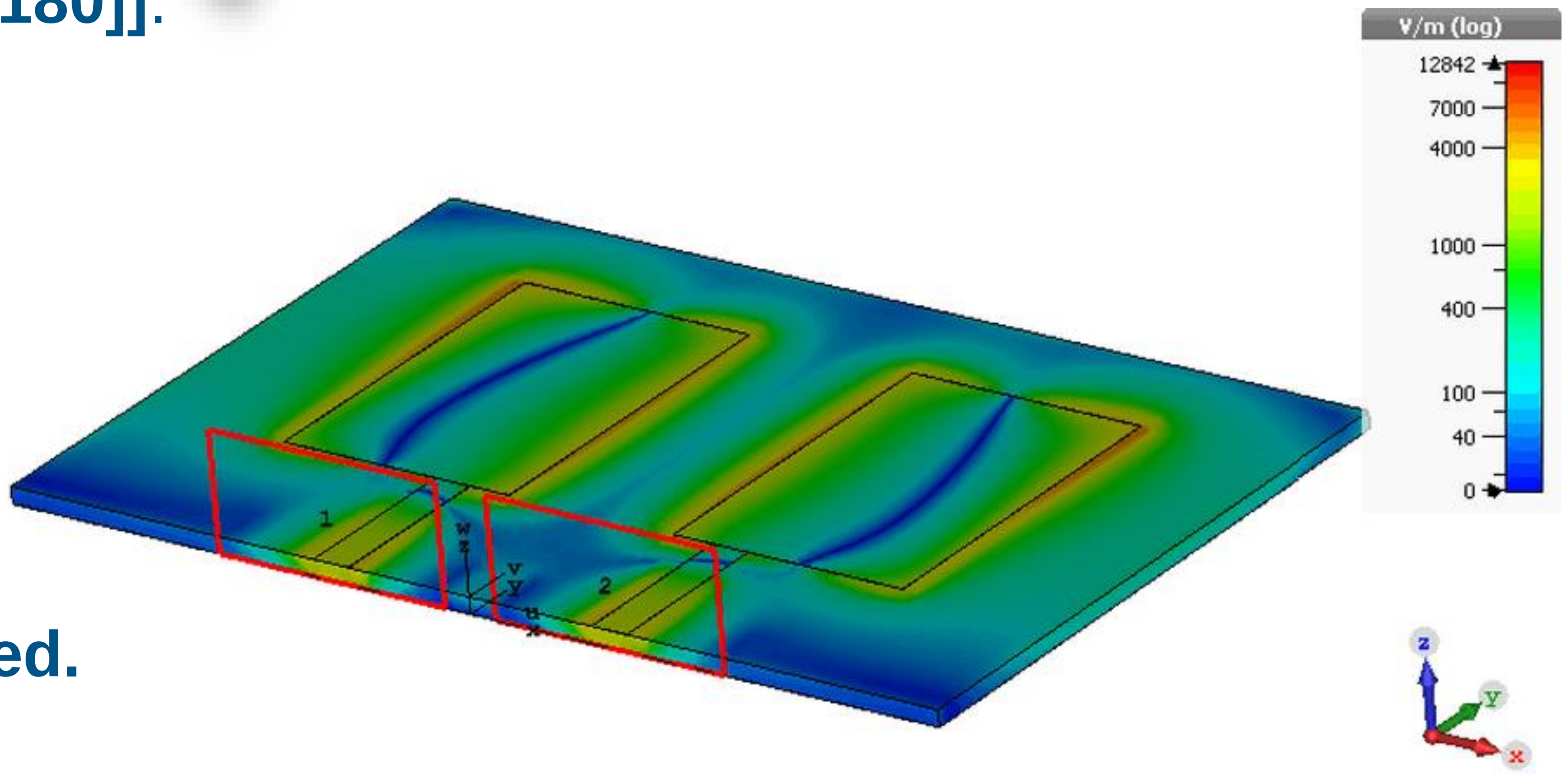


Combine Results (3/4)



4. Select **E-Field > e-field (f=3.4)[1[1,0]+2[1,180]]**.

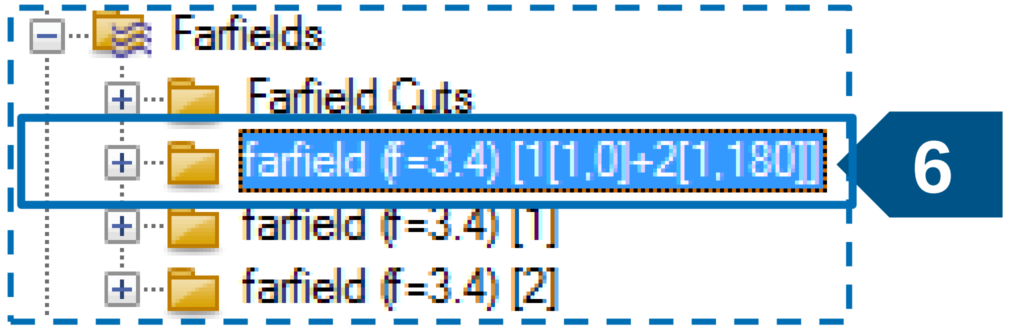
5. Specify field plot settings.
    a. Set Contour plot.
    b. Apply Smart Scaling.
    c. Animate Fields.

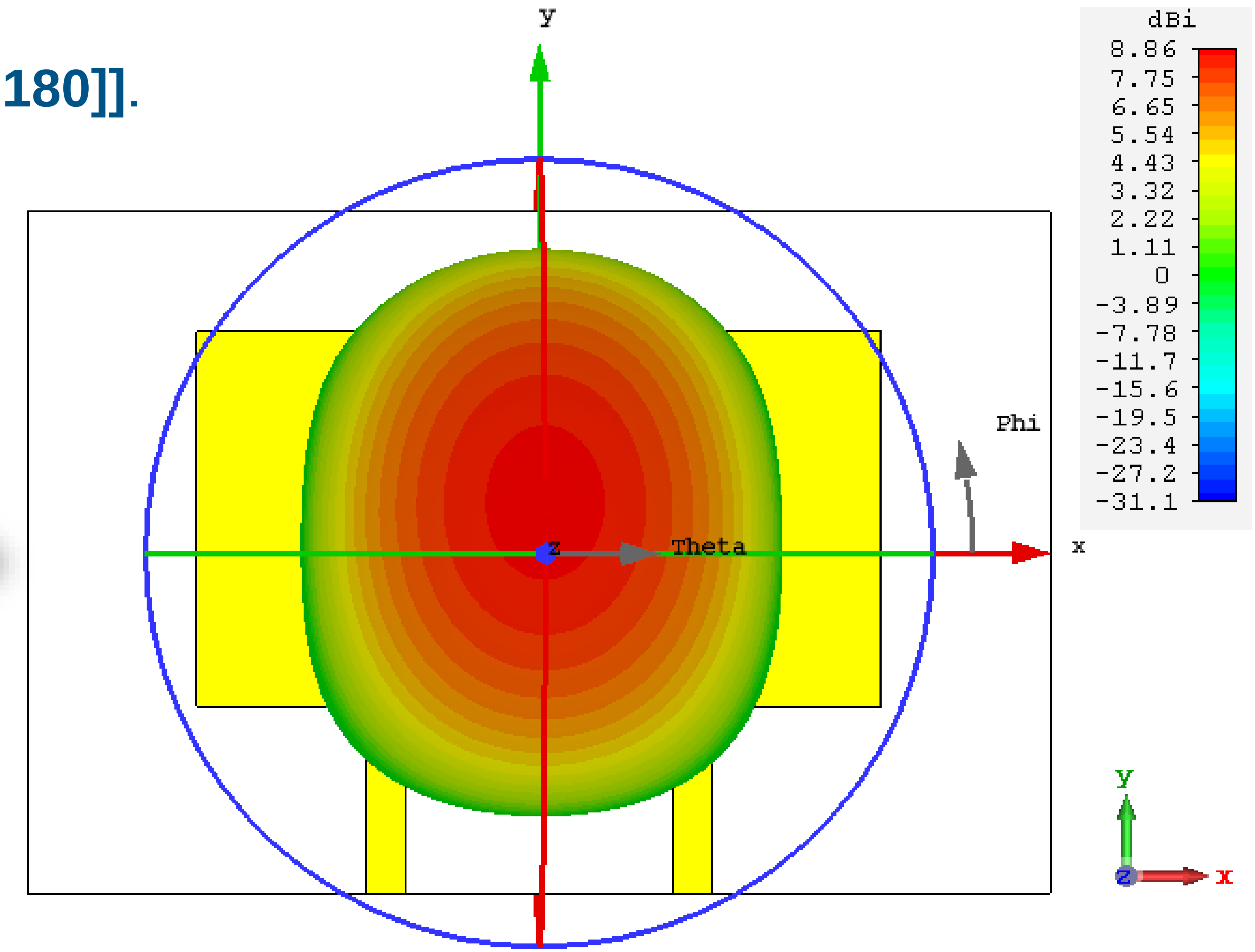


Port 1 and Port 2 are simultaneously excited.

Combine Results (4/4)

6. Select **Farfields > farfield (f=3.4)[1[1,0]+2[1,180]]**.



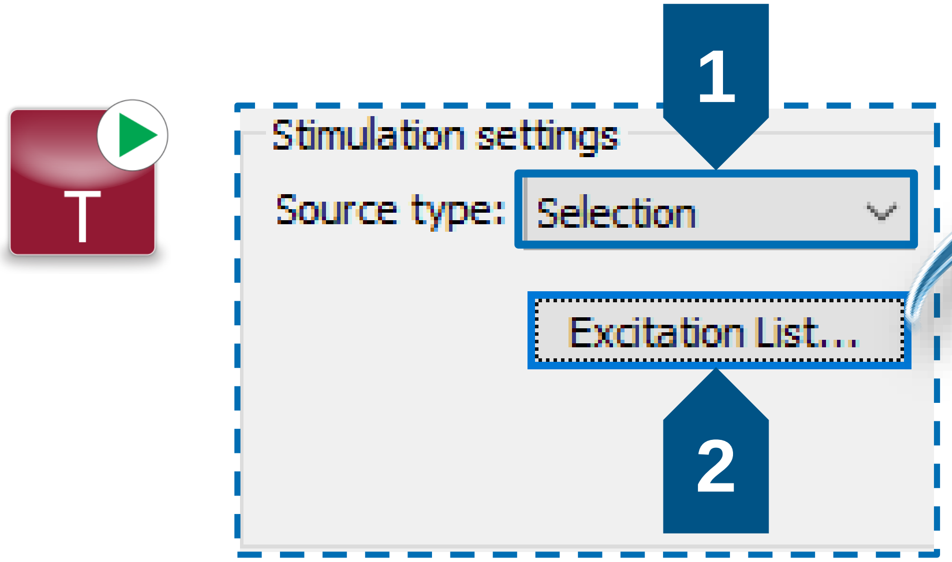


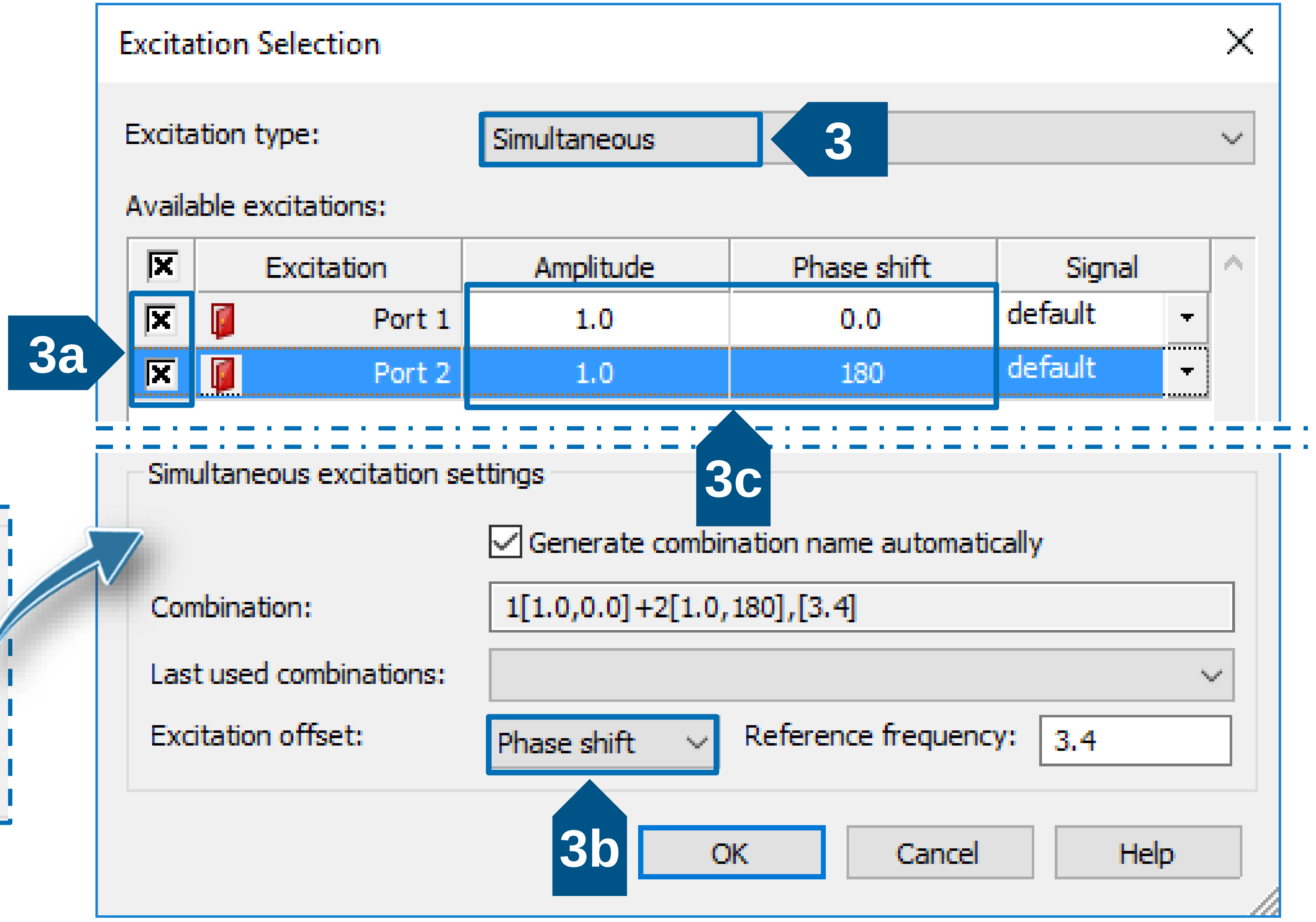
The combined excitation results in a higher directivity for the antenna (8.86 dBi) compared to the single excitation case (6.56 dBi).

Simultaneous Excitation - Info Slide

For larger array composed by hundreds/ thousands of port it's more efficient in terms of computational time to perform directly a simulation using a **Simultaneous excitation**.

1. Set **Selection** as Source Type.
2. Open **Excitation list** dialog box.
3. Set **Simultaneous** as Excitation Type.
   a. Set active ports.
   b. Set Phase shift.
   c. Set Am & Ph of each port.

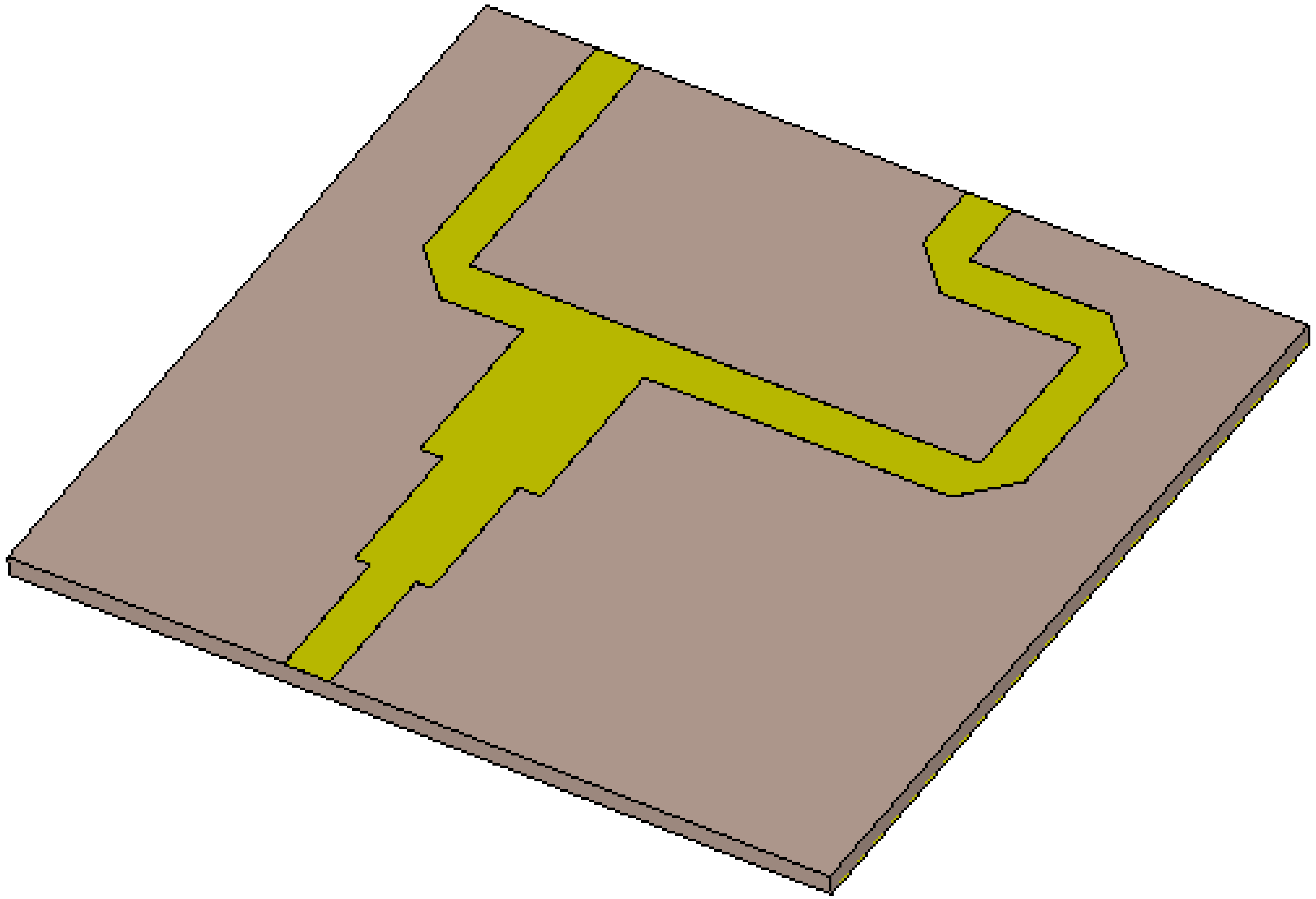




In a simultaneous excitation the phase shift is only valid at the reference frequency.

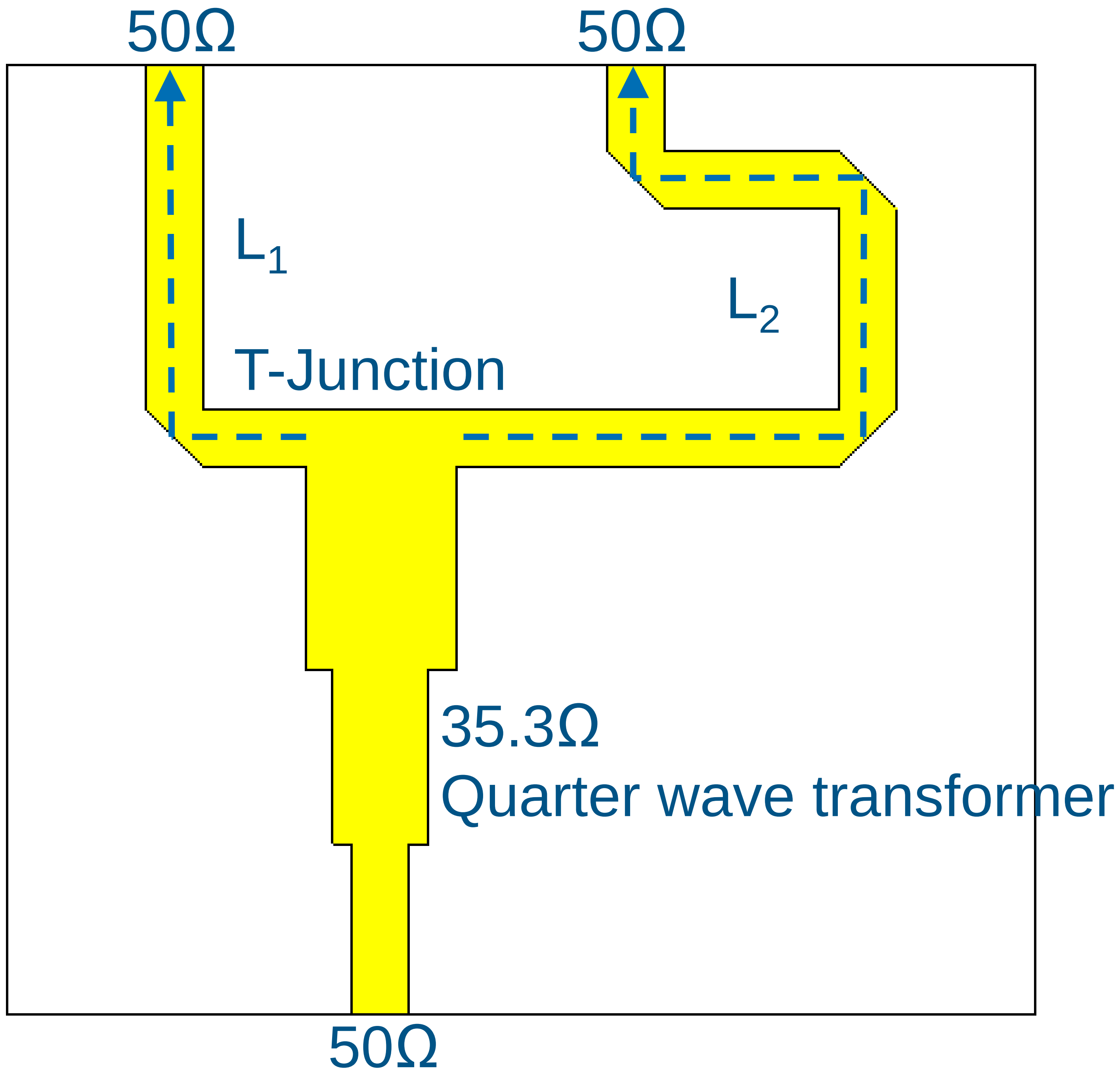
Microstrip Feeding Network Info (1/2)

In the following part we are going to create the feeding network model below using the Schematic (**CST DESIGN STUDIO**) of CST STUDIO SUITE.



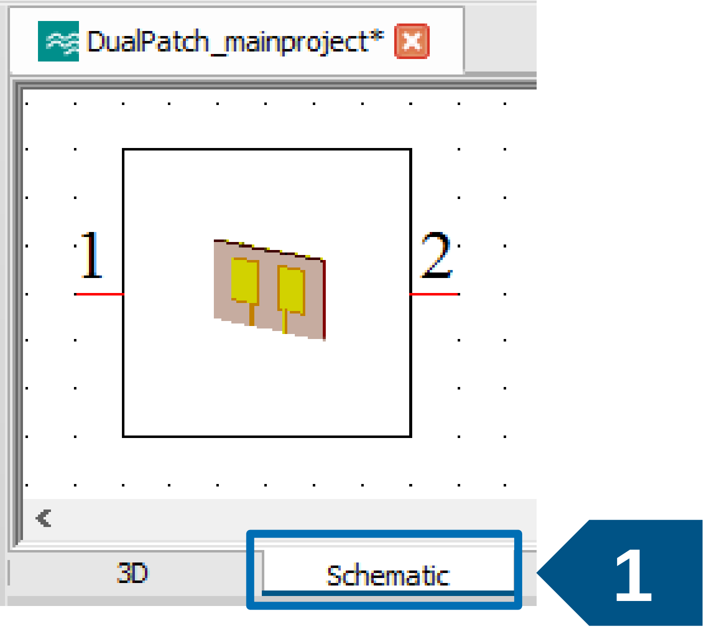
Microstrip Feeding Network Info (2/2)

The patches need to be fed 180º out of phase. Phase difference $L_2 - L_1 = \lambda/2$. The splitter is designed so that one arm is 180° longer on the 3.4GHz.

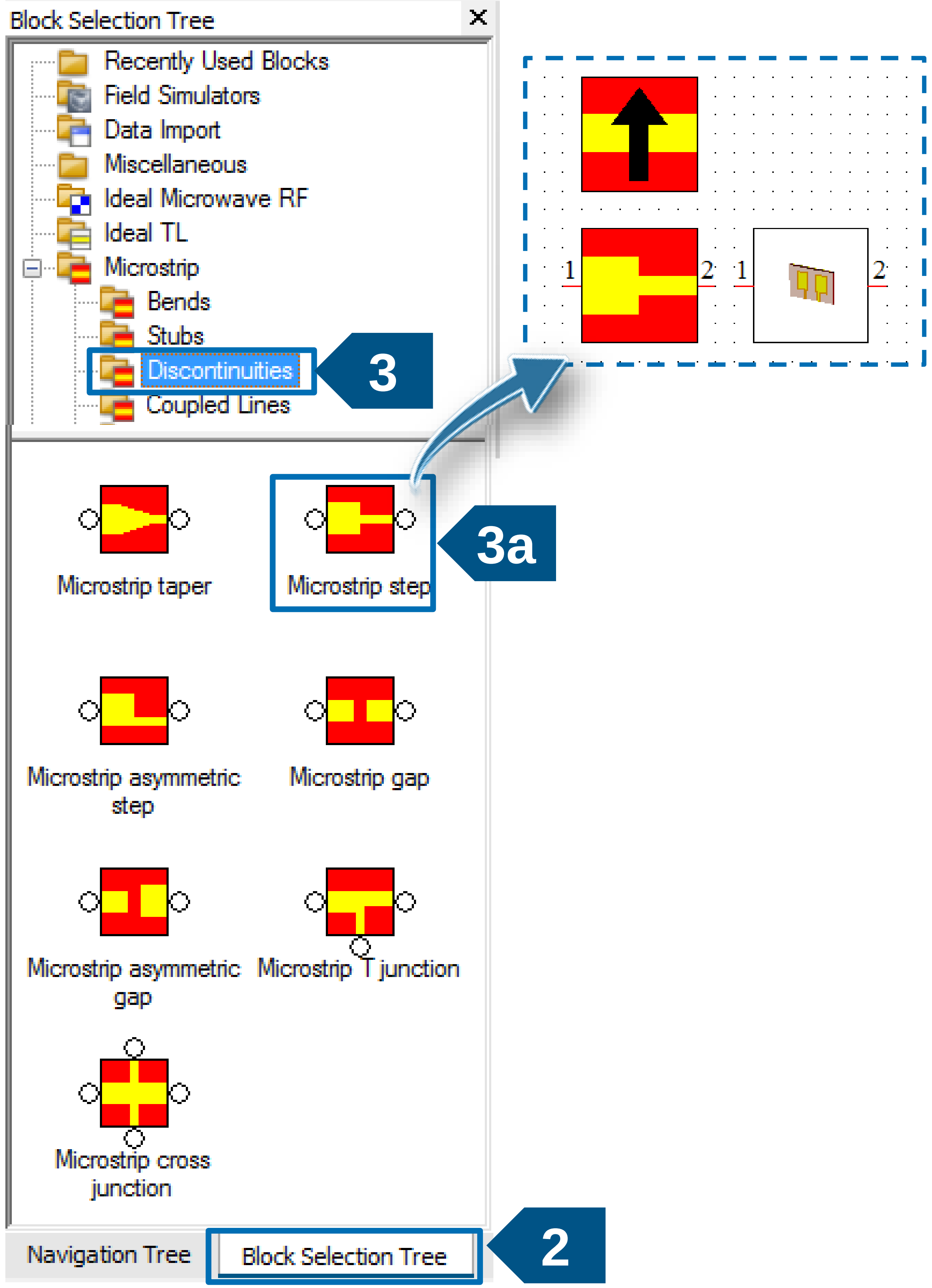


Microstrip Feeding Network Modeling (1/6)

1. Go to the **Schematic** associated to the 3D model.

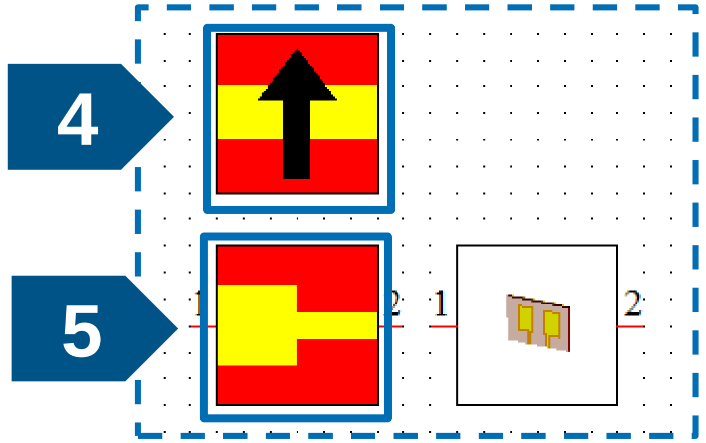


2. Open the **Block Selection Tree.**
3. Select **Microstrip > Discountinuities.**
   a. Drag & Drop **Microstrip step** into the Schematic.



Microstrip Feeding Network Modeling (2/6)

4. Select **Microstrip Reference Block** to specify the substrate parameters.
   a. Enter values shown in the picture below left.
5. Select **Microstrip Step**.
   a. Enter values shown in the picture below right.



Block Parameter List (MSREF1)

Name	Expression
Number Of Layers	1
Height[1]	1.52
Thickness[1]	0.018
Epsilon[1]	3.5
Tandelta[1]	0.0018
Rho[1]	0.0
Roughness[1]	0.0
Ground Plate Thickness	0.018
Ground Plate Rho	0.0
Ground Plate Roughness	0.0
External Port in Layout	Discrete Face Port
Substrate Xmin	0
Substrate Xmax	0
Substrate Ymin	29.8
Substrate Ymax	16.23
Absolute substrate dimensions	☐
Use as default reference	☑

4a

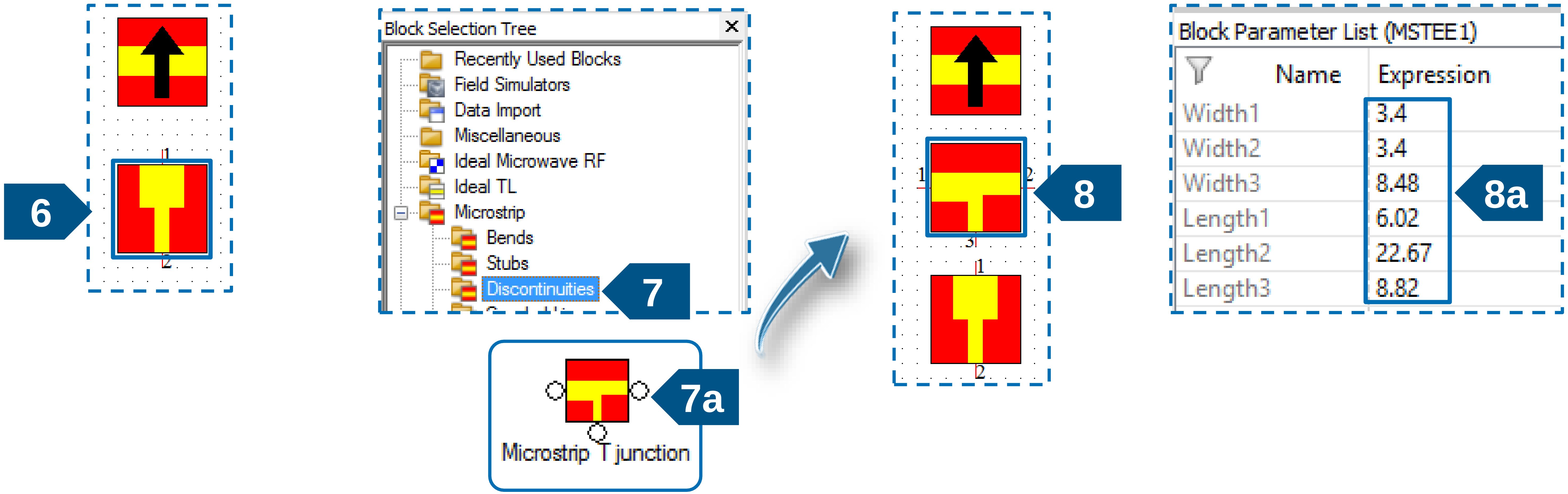
Block Parameter List (MSSTEP1)

Name	Expression
Width1	5.57
Width2	3.4
Length1	8.41
Length2	10

5a

Microstrip Feeding Network Modeling (3/6)

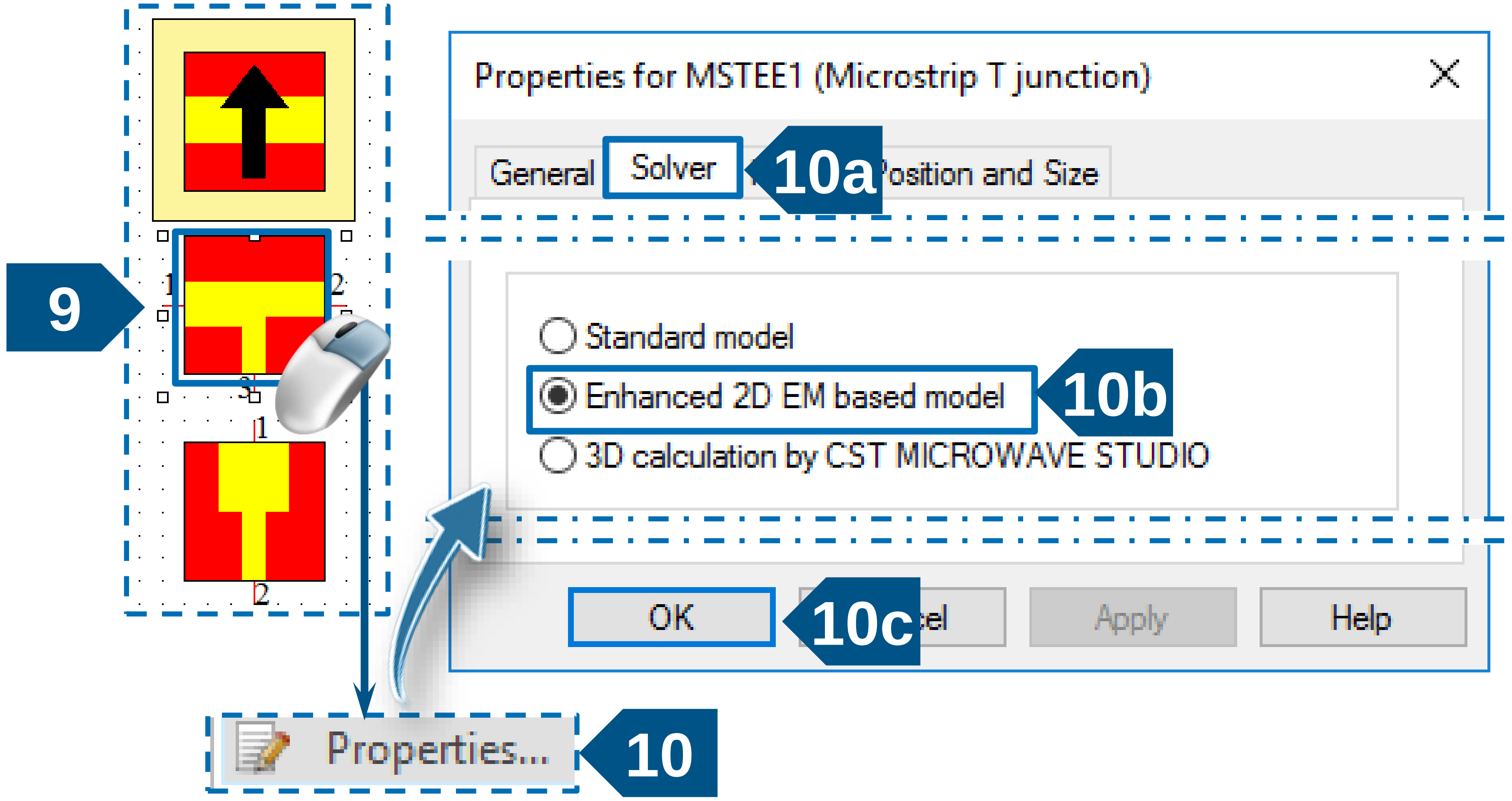
6. Select Microstrip Step and **rotate it by 90° (**hotkey R).
7. Select **Microstrip > Discountinuities.**
    a. Drag & Drop **Microstrip T-junction** into the Schematic.
8. Select **Microstrip T-junction** block in the Schematic.
    a. Enter values shown in the picture below left.



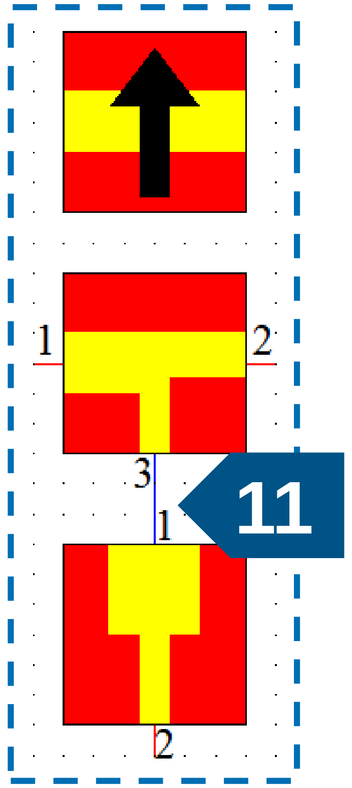
Name	Expression
Width1	3.4
Width2	3.4
Width3	8.48
Length1	6.02
Length2	22.67
Length3	8.82

Microstrip Feeding Network Modeling (4/6)

9. Right click on the T-Junction block.
10. Open block **Properties**.
    a. Set Solver.
    b. Set **Enhanced 2D EM based model.**
    c. OK to confirm.

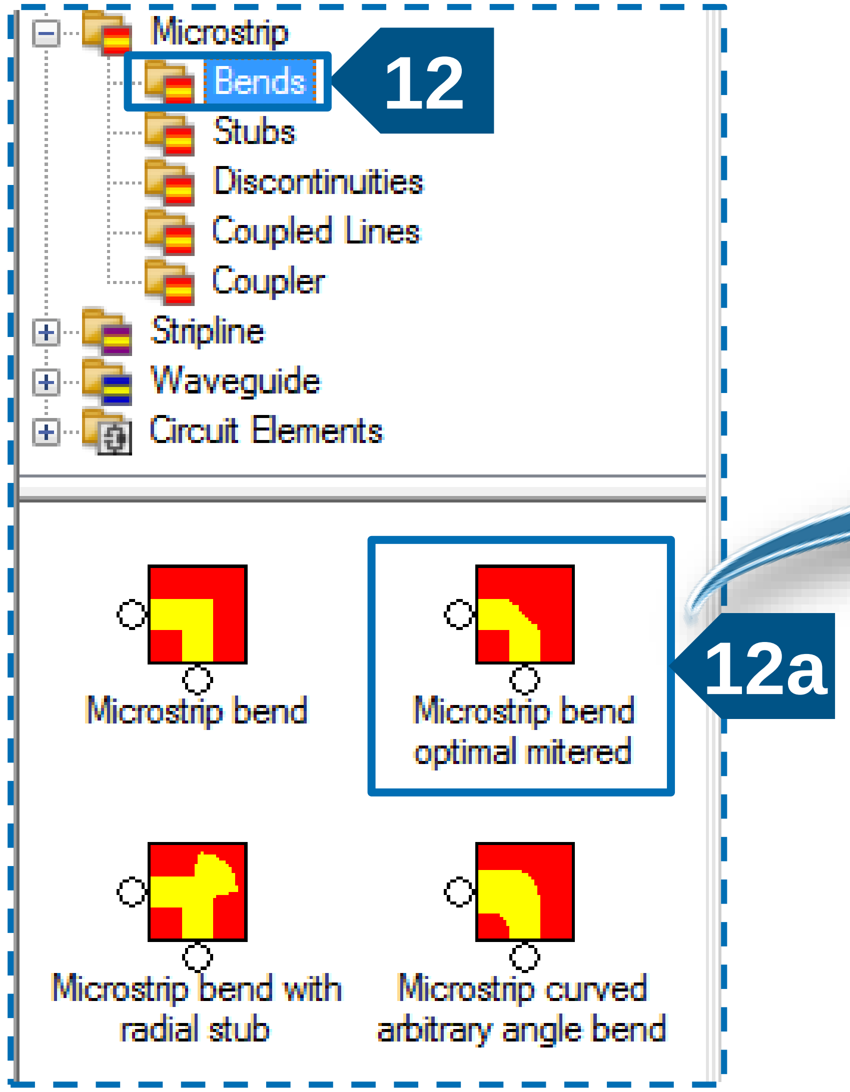


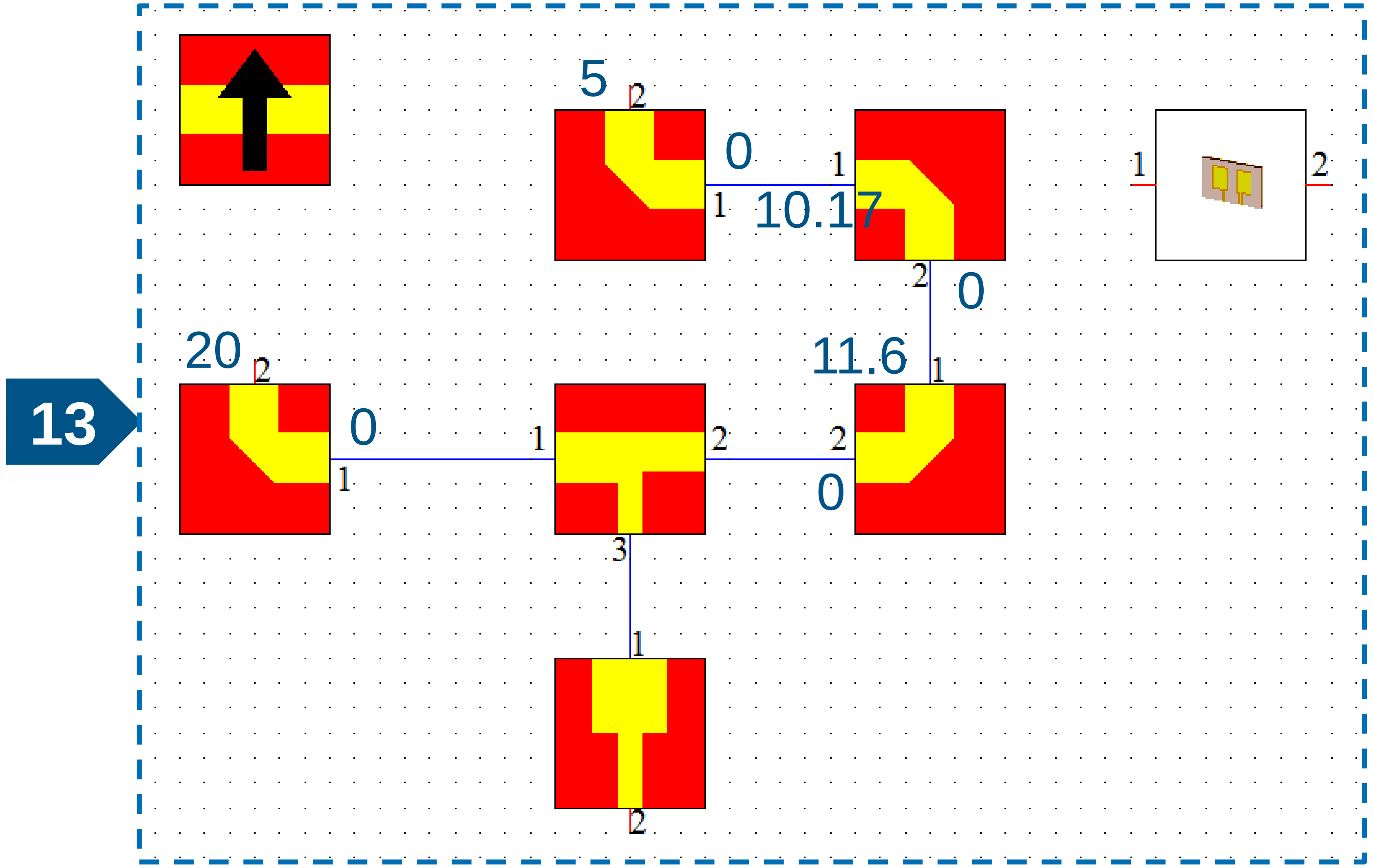
11. Connect pin 3 of the T-junction to pin 1 of the step discontinuity (hotkey C).



Microstrip Feeding Network Modeling (5/6)

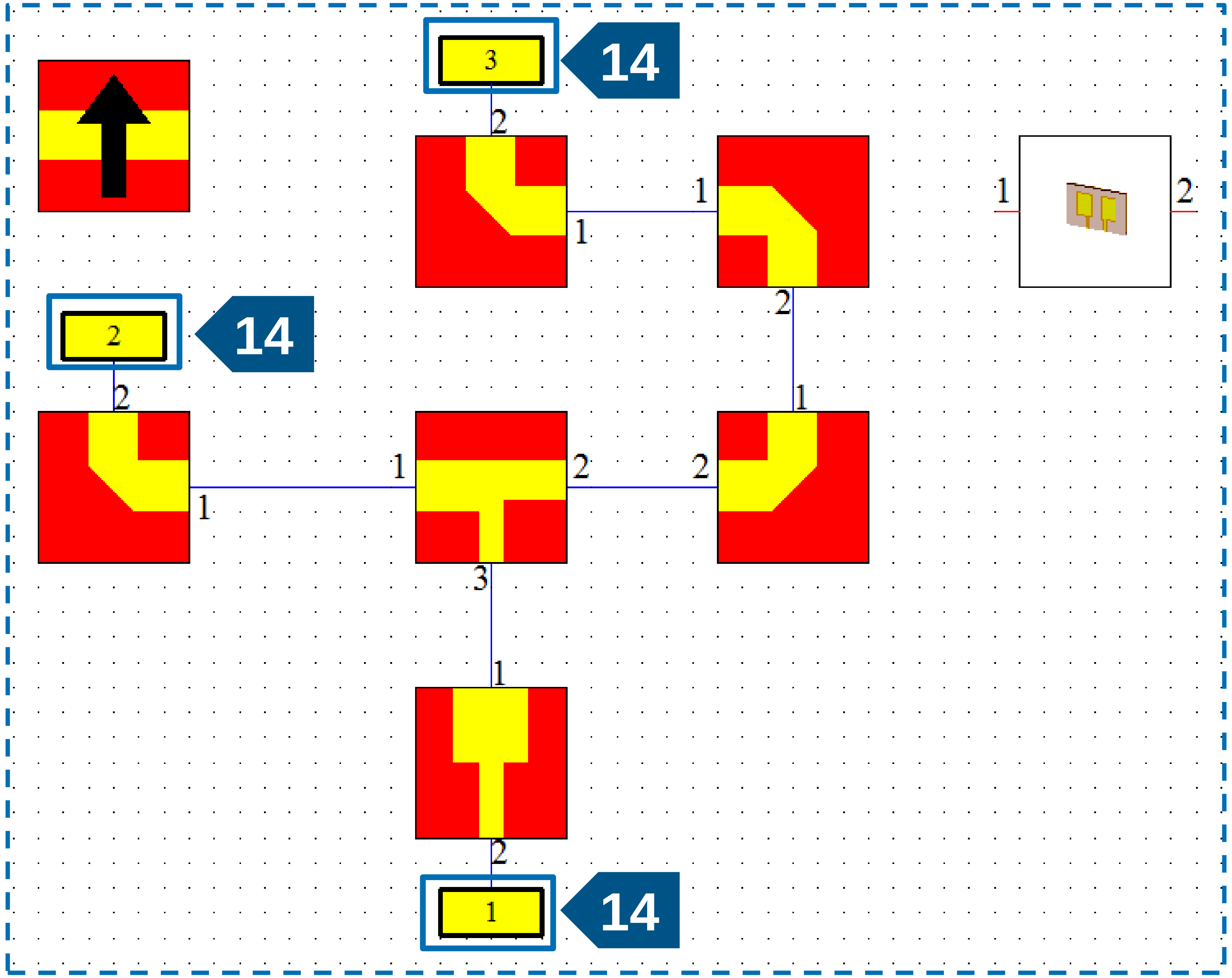
12. Select **Microstrip > Bends.**
    a. Drag & Drop 4 times a **Microstrip bend optimal mitered** into the Schematic.
13. Rotate & Connect blocks together as shown in the picture below. Set all **Bend Width=3.4 mm.** Set **lengths** as shown in the picture below.





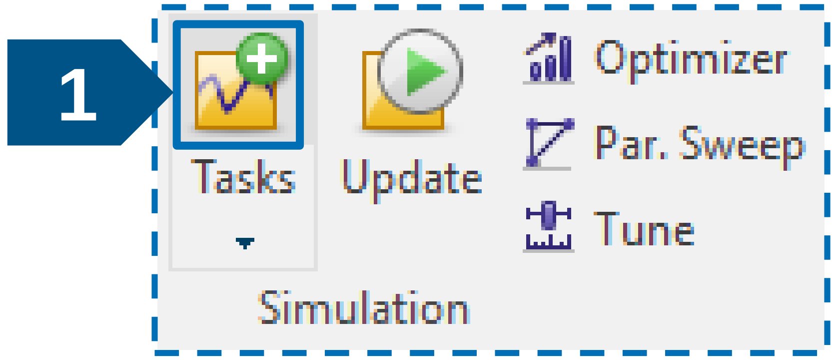
Microstrip Feeding Network Modeling (6/6)

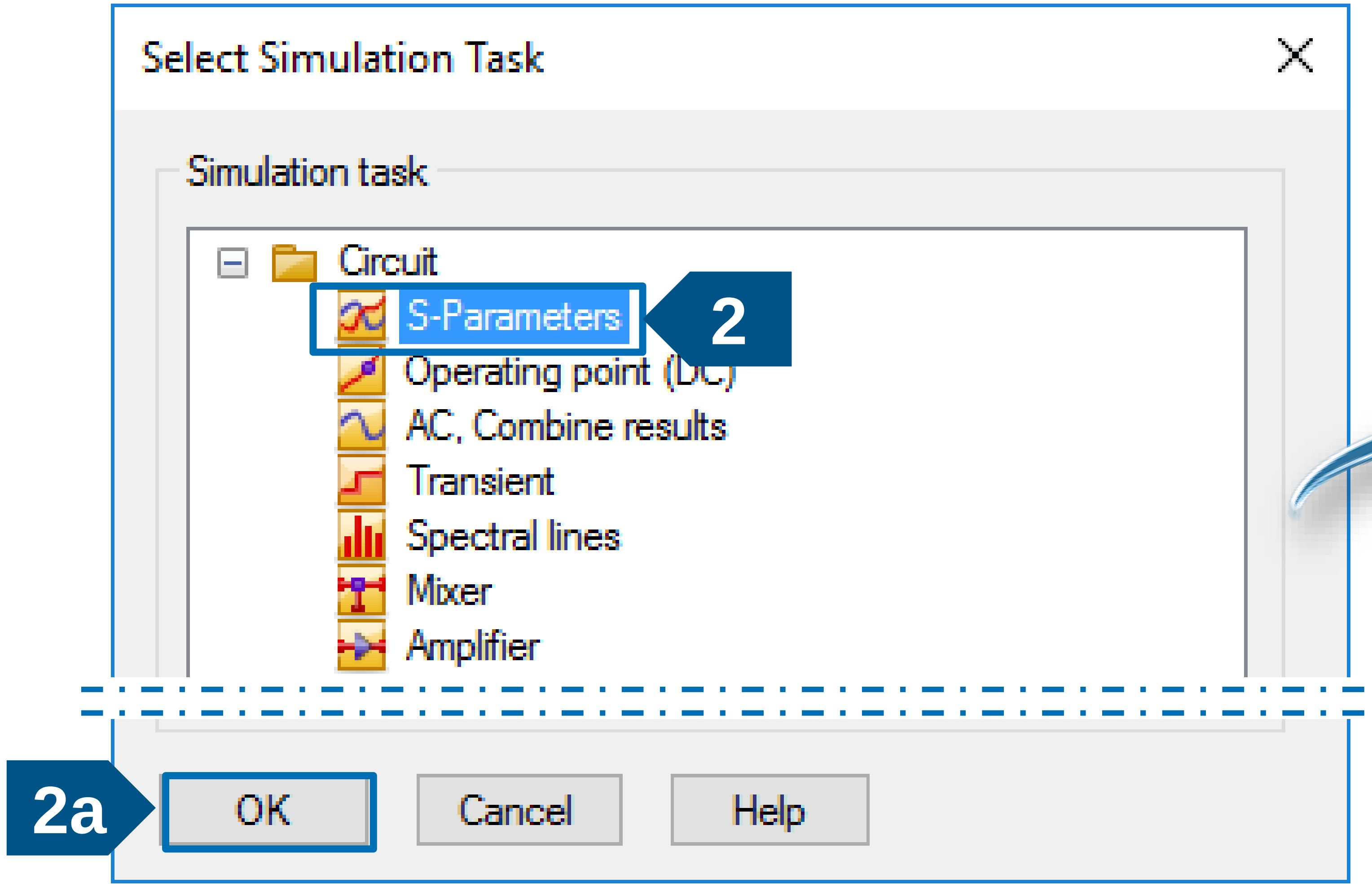
14. Connect three external ports (hotkey P) to the open pins as shown below. Leave the antenna block disconnected.

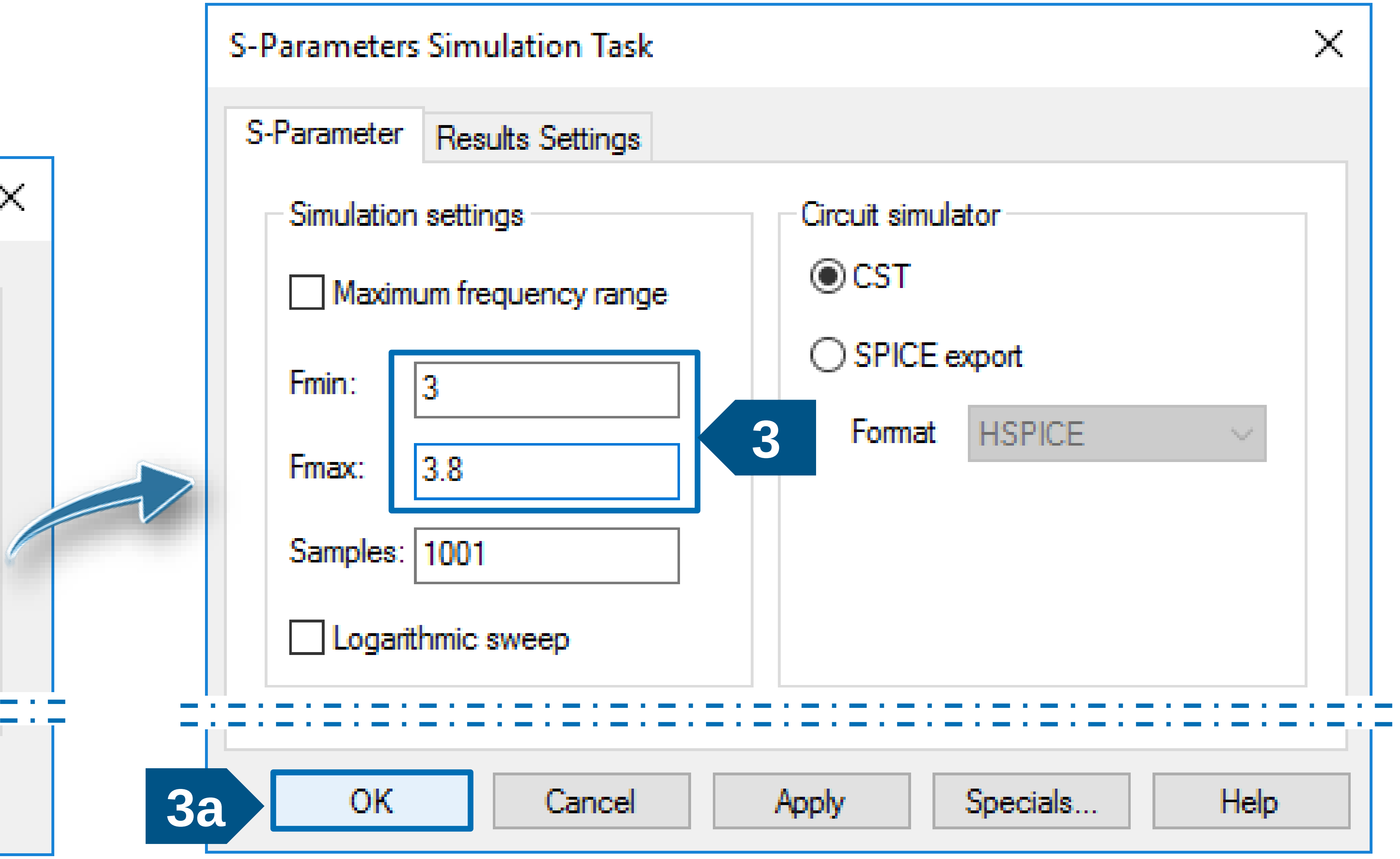


S-Parameters Simulation (1/2)

1. Define New Task.
2. Select S-Parameter Task.
    a. Click OK to open the dialog box.
3. Set S-Parameter task frequency range.
    a. OK to confirm.

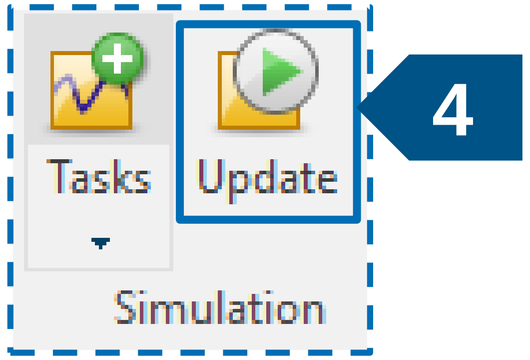


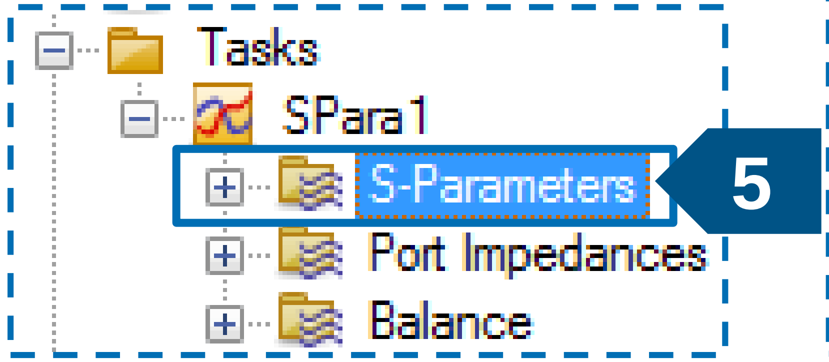


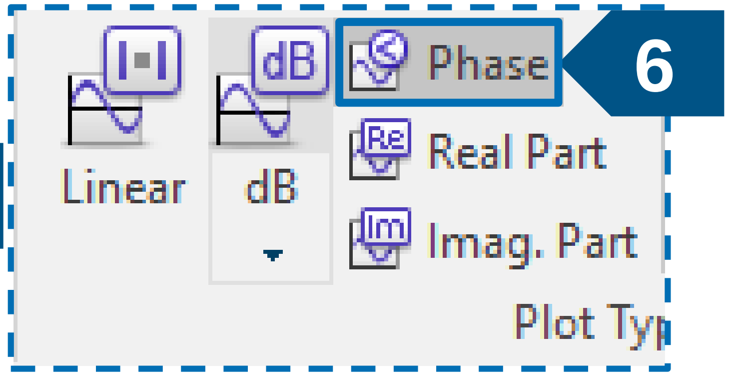


S-Parameters Simulation (2/2)

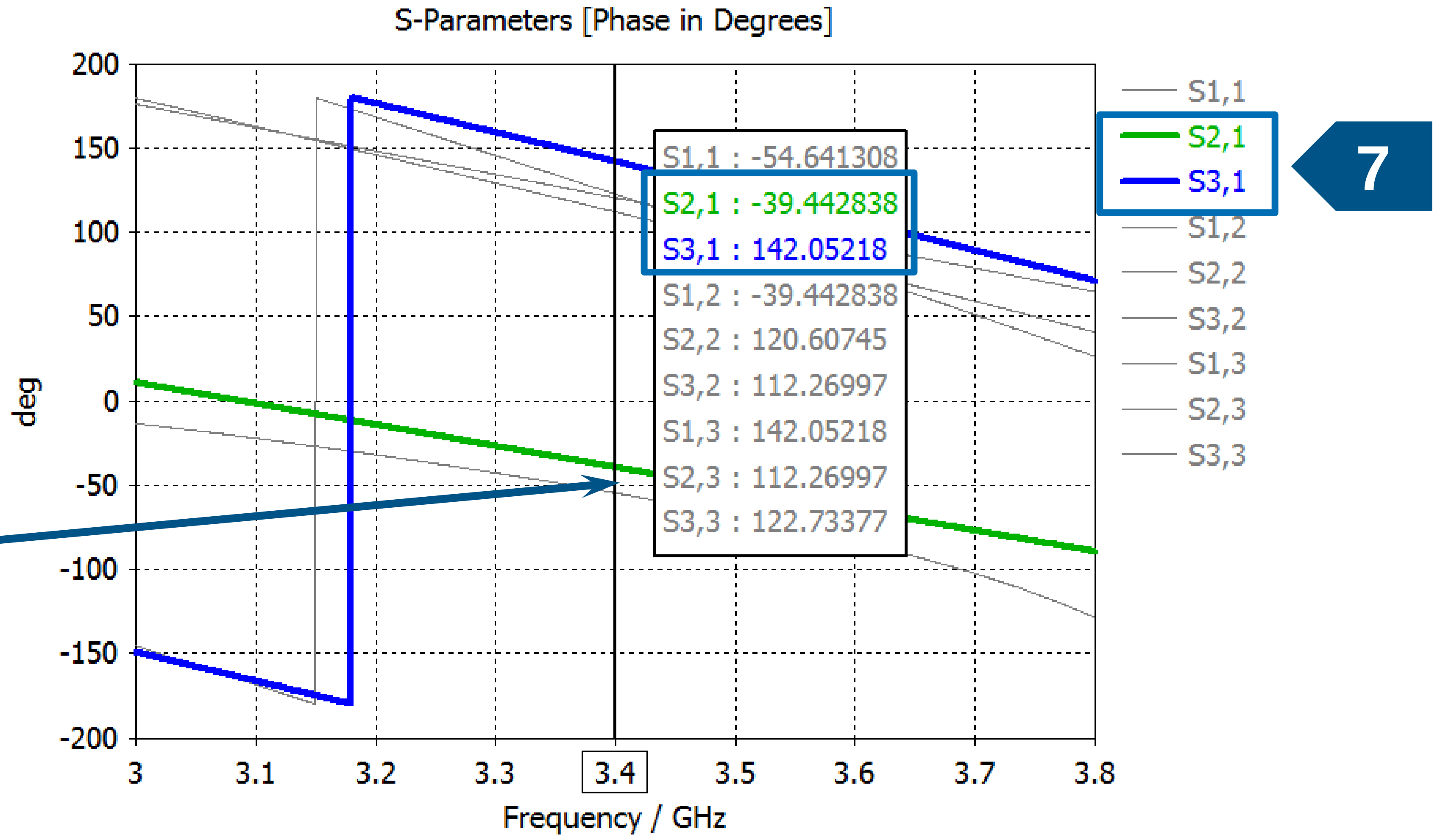
4. Launch the **Update** of the tasks.
5. Visualize S-Parameters.
6. Plot Phase from 1D Ribbon.







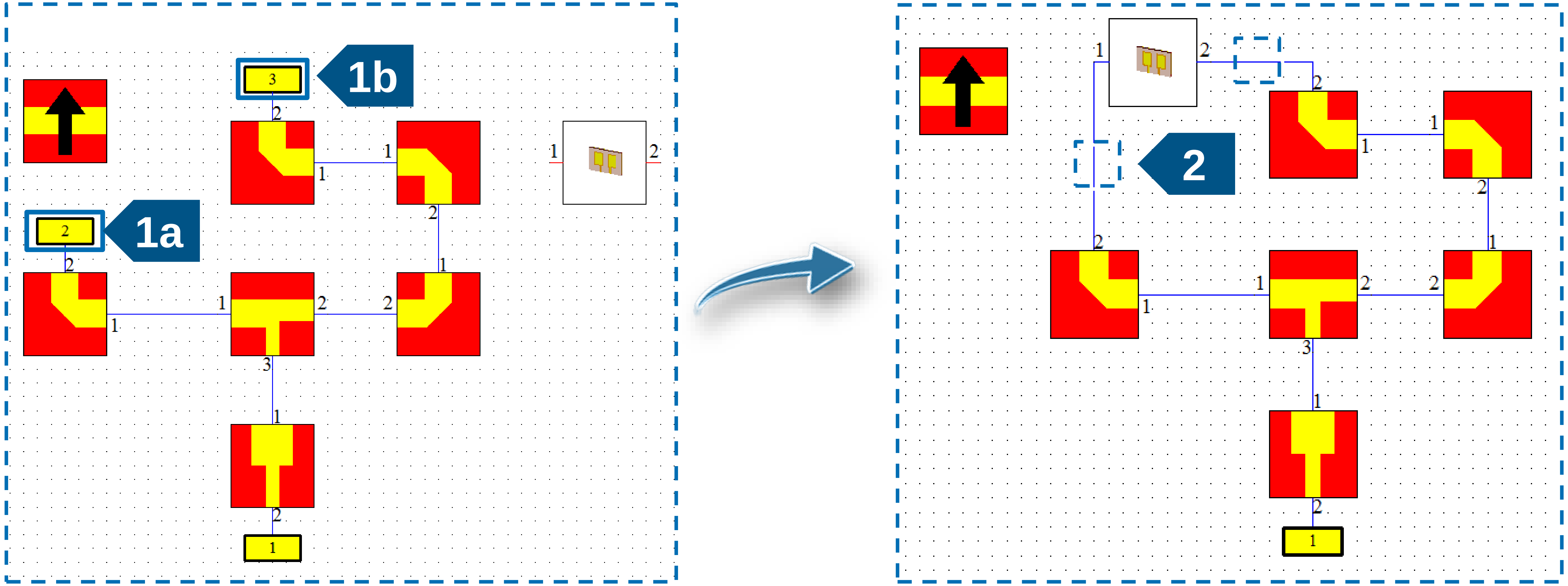
7. Highlight S2,1 & S3,1 curves from the plot using multiple select.
8. Right click on plot and activate Show Axis Marker.



The Phase difference is around 180°.

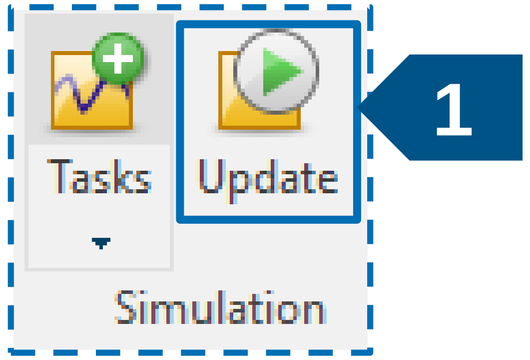
Connect 2D Feeding Network to Dual Patch Antenna

1. Remove (hotkey CANC) External Ports.
   a. Select & **Delete Port 2**.
   b. Select & **Delete Port 3**.
2. Connect (C) the open pins of the antenna block to the feeding network open pins.



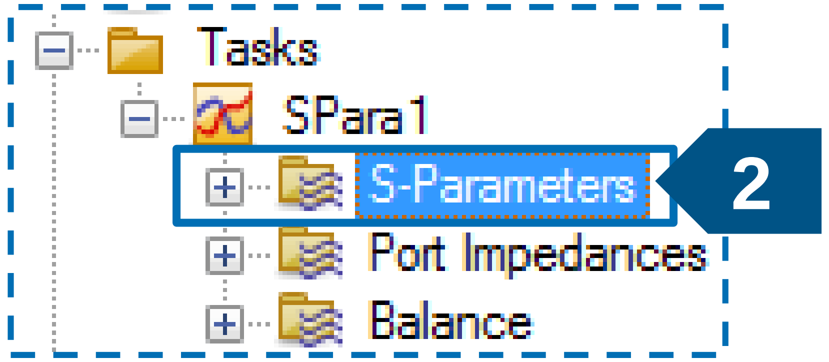
S-Parameters Simulation

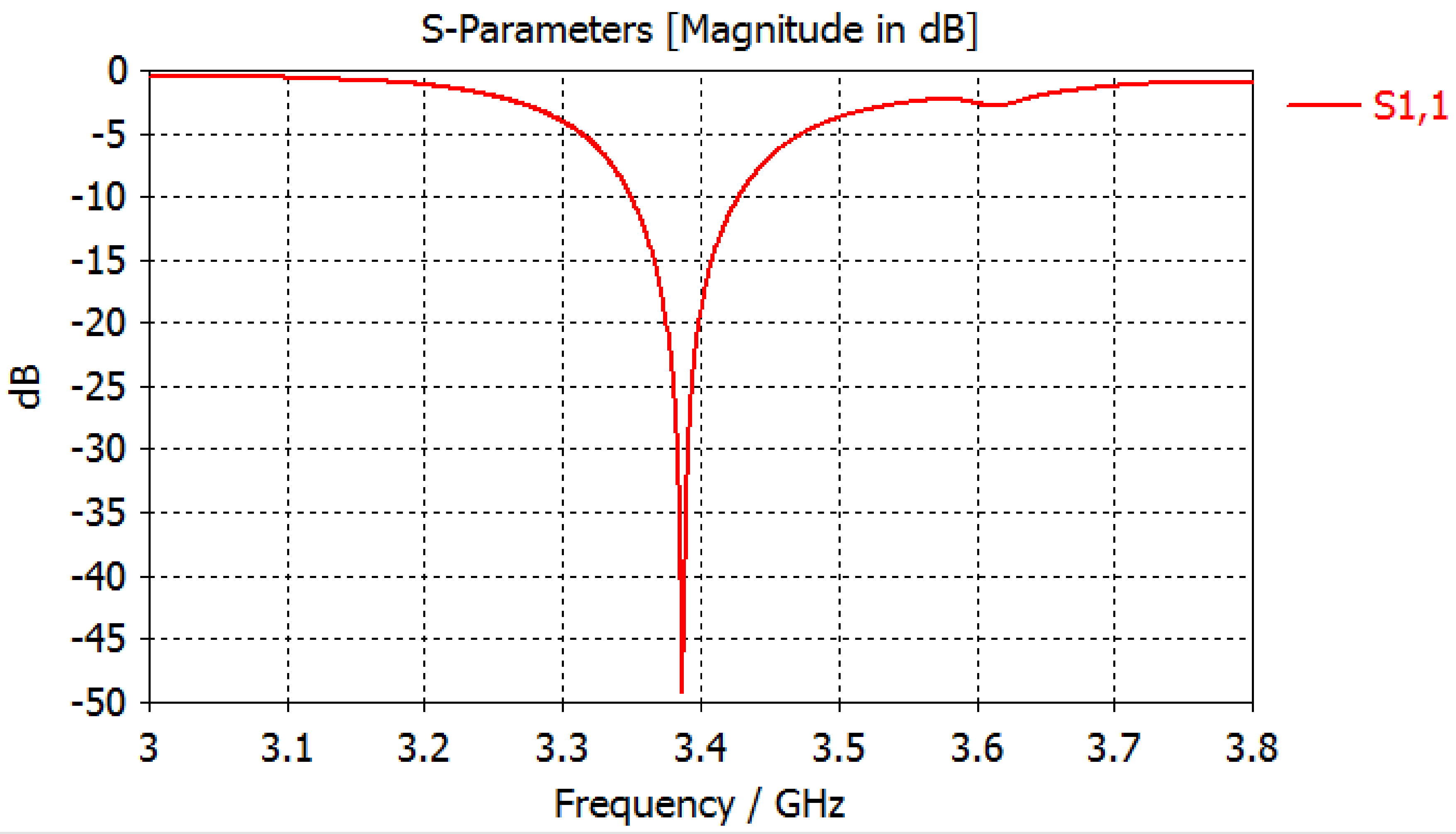
1. Launch the **Update** of the tasks.



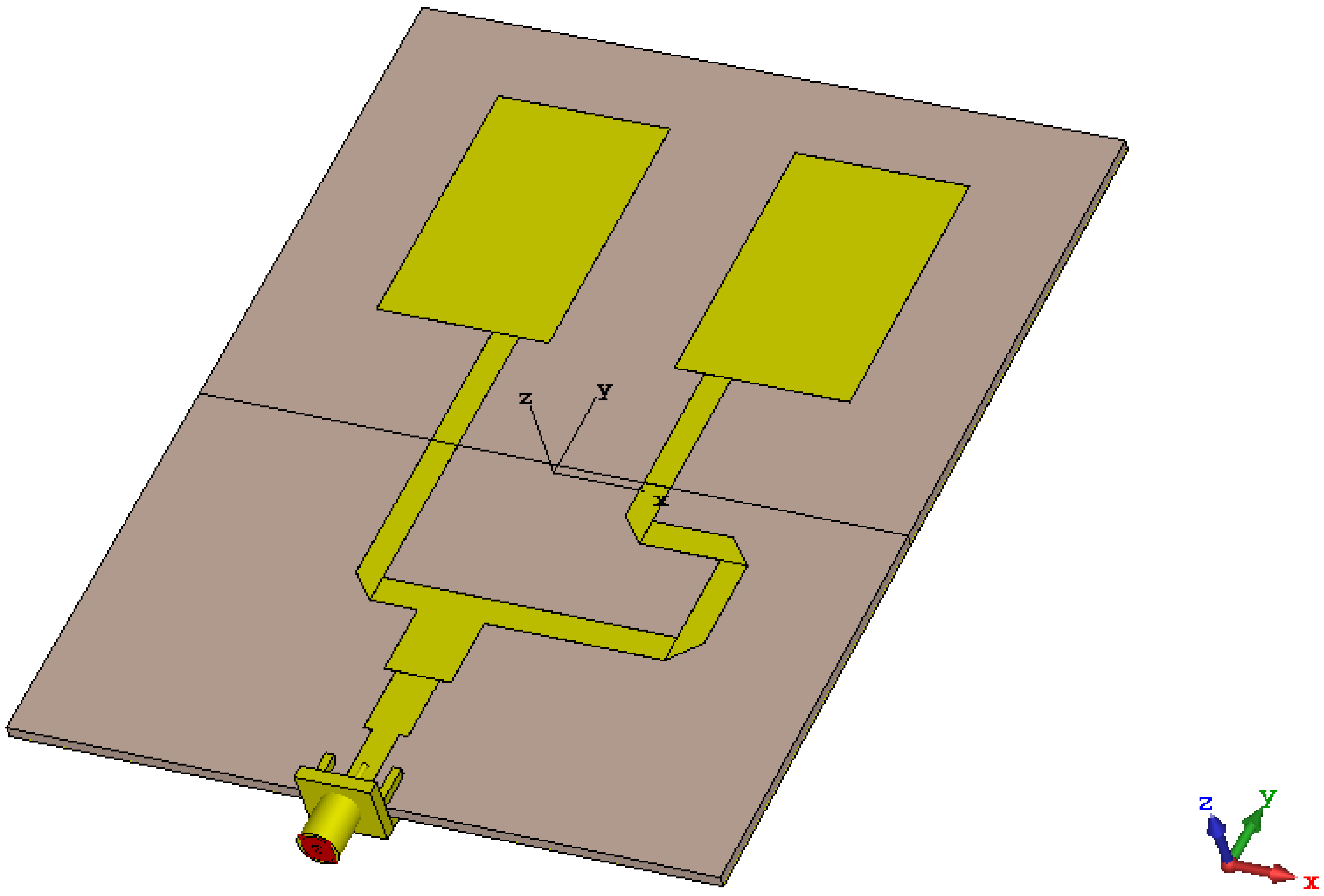
The simulation is extremely fast because only a circuital simulation, cascading the S-Parameters blocks (2D simulation of feeding network + antenna S-Matrix previously calculated), has to be performed.

2. Visualize S-Parameters.





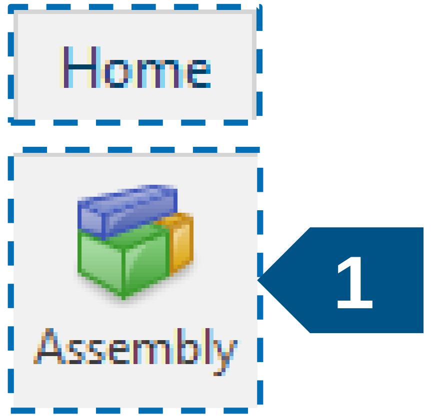
Simulate the Feeding Network, the SMA connector and the Antenna

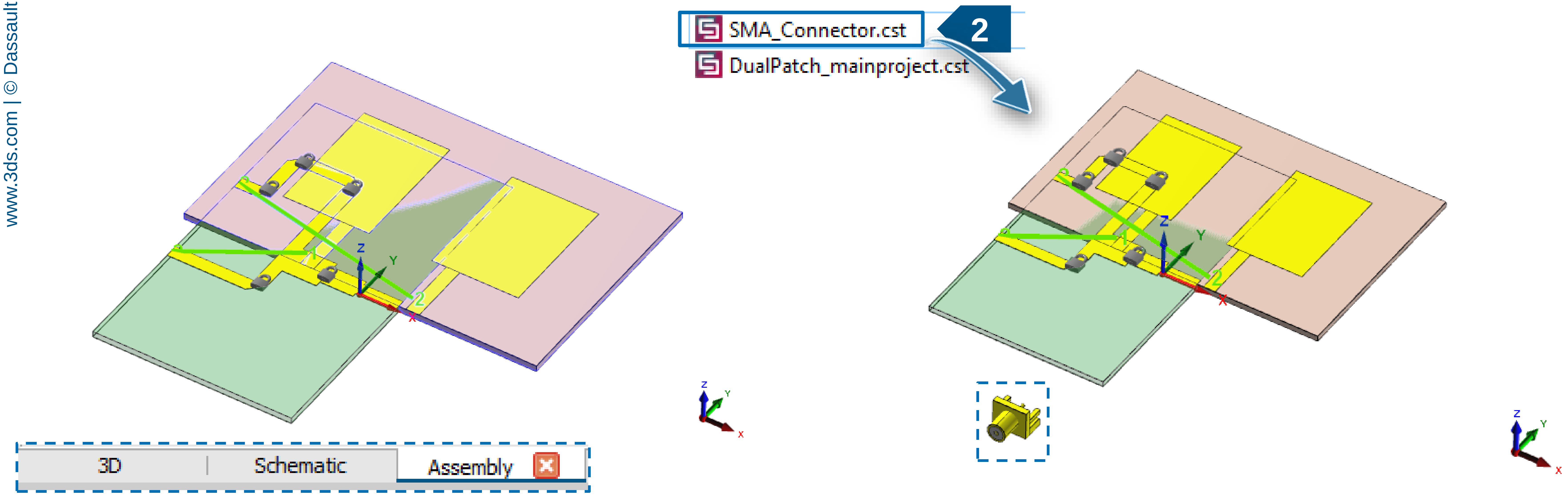


Import SMA connector in the Assembly View

1. Open the Assembly View to see all blocks assembled in 3D.

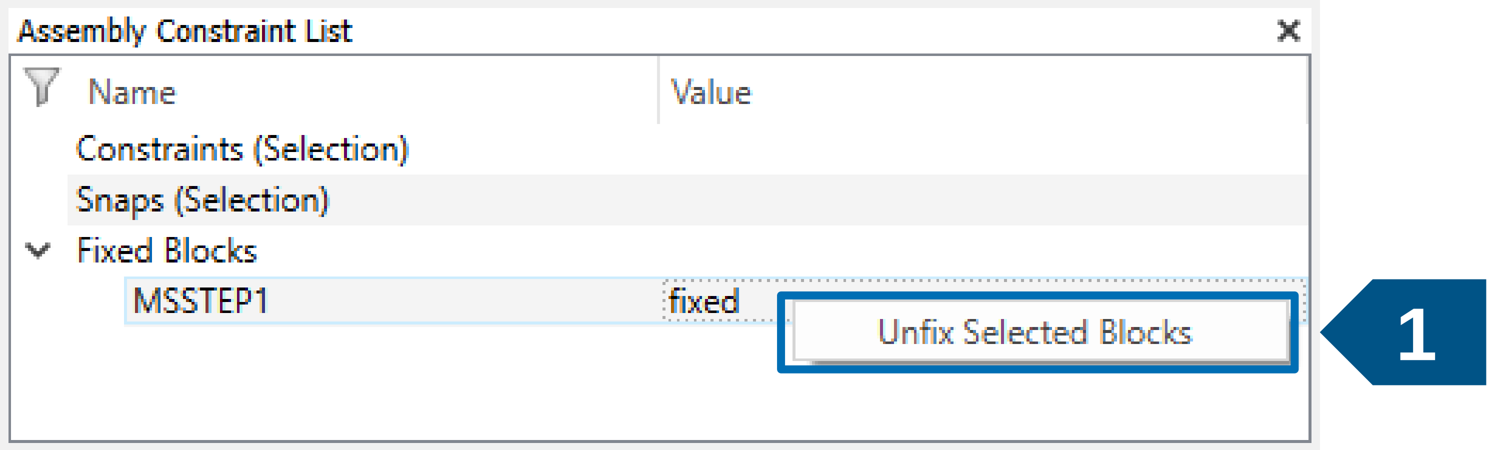
2. Drag & Drop **"SMA_Connector.cst"** file into the Assembly from Windows Explorer.



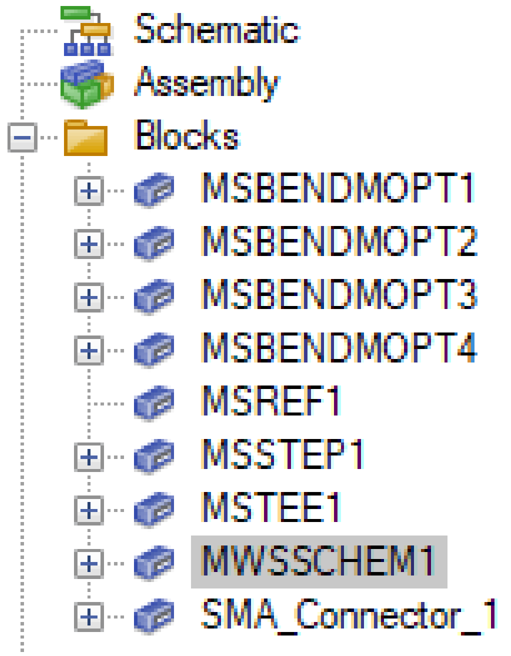


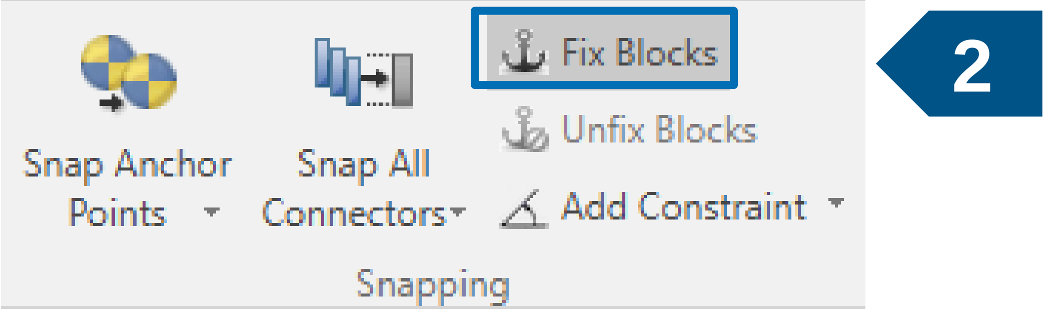
Block alignment in the Assembly View (1/7)

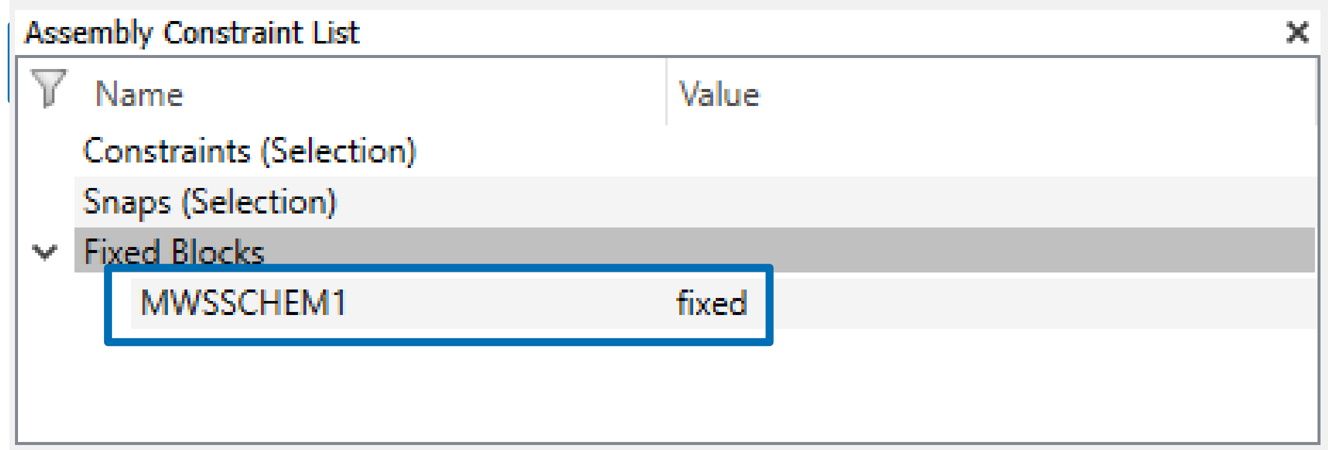
1. Unfix the MSSTEP1 component.

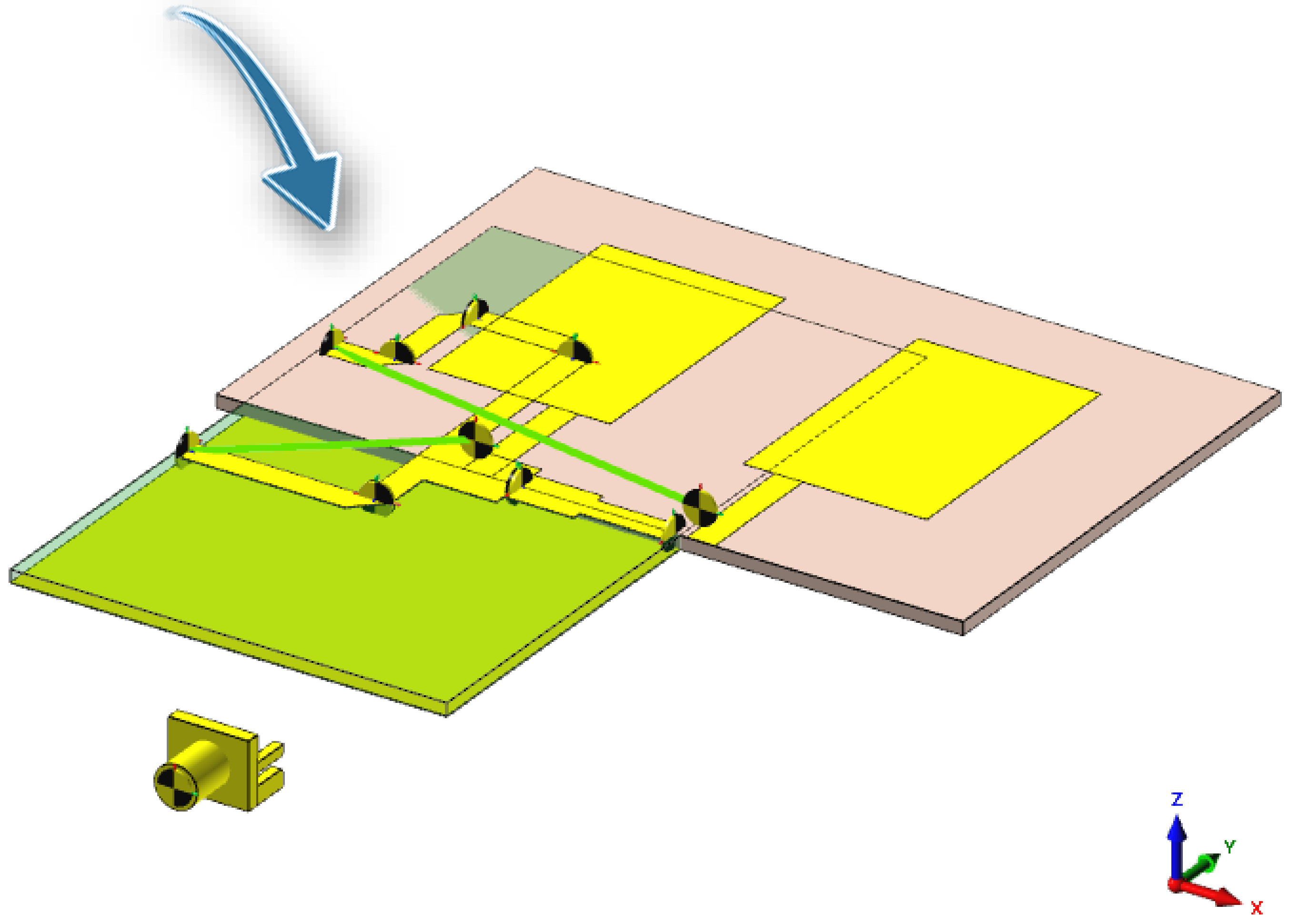


2. Select MWSSCHEM1 (Dual patch 3D part) in navigation tree and fix the position.



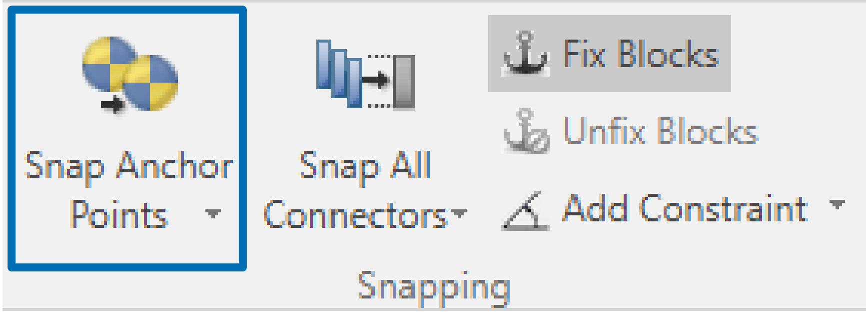






Block alignment in the Assembly View (2/7)

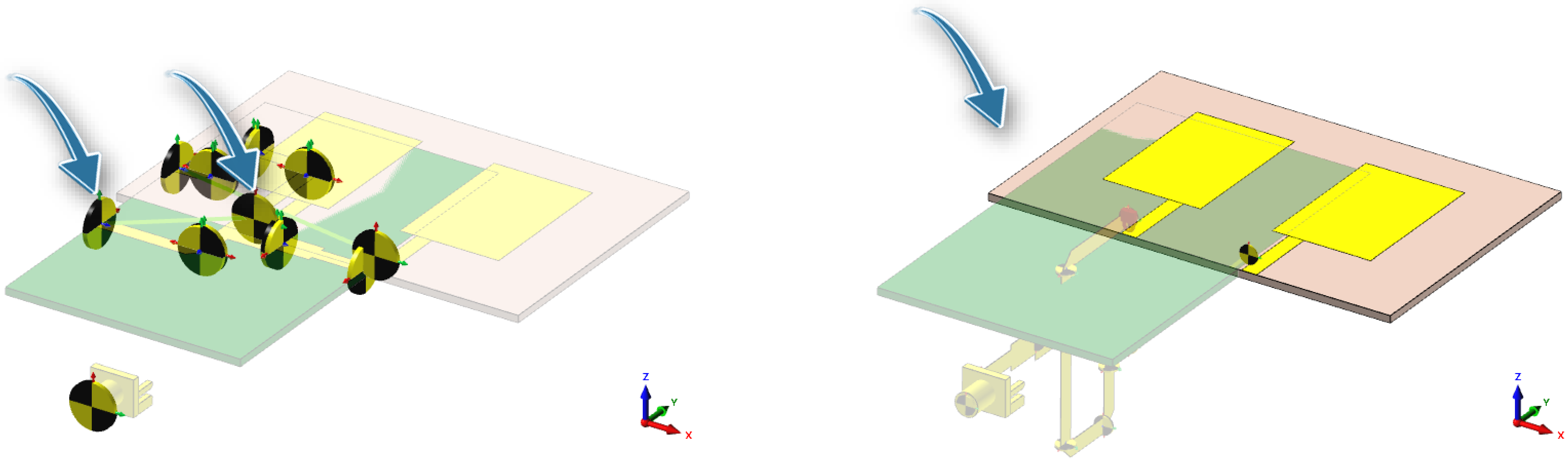
3. Snap all Components.



3

4. Select two corresponding anchor points and confirm snapping.

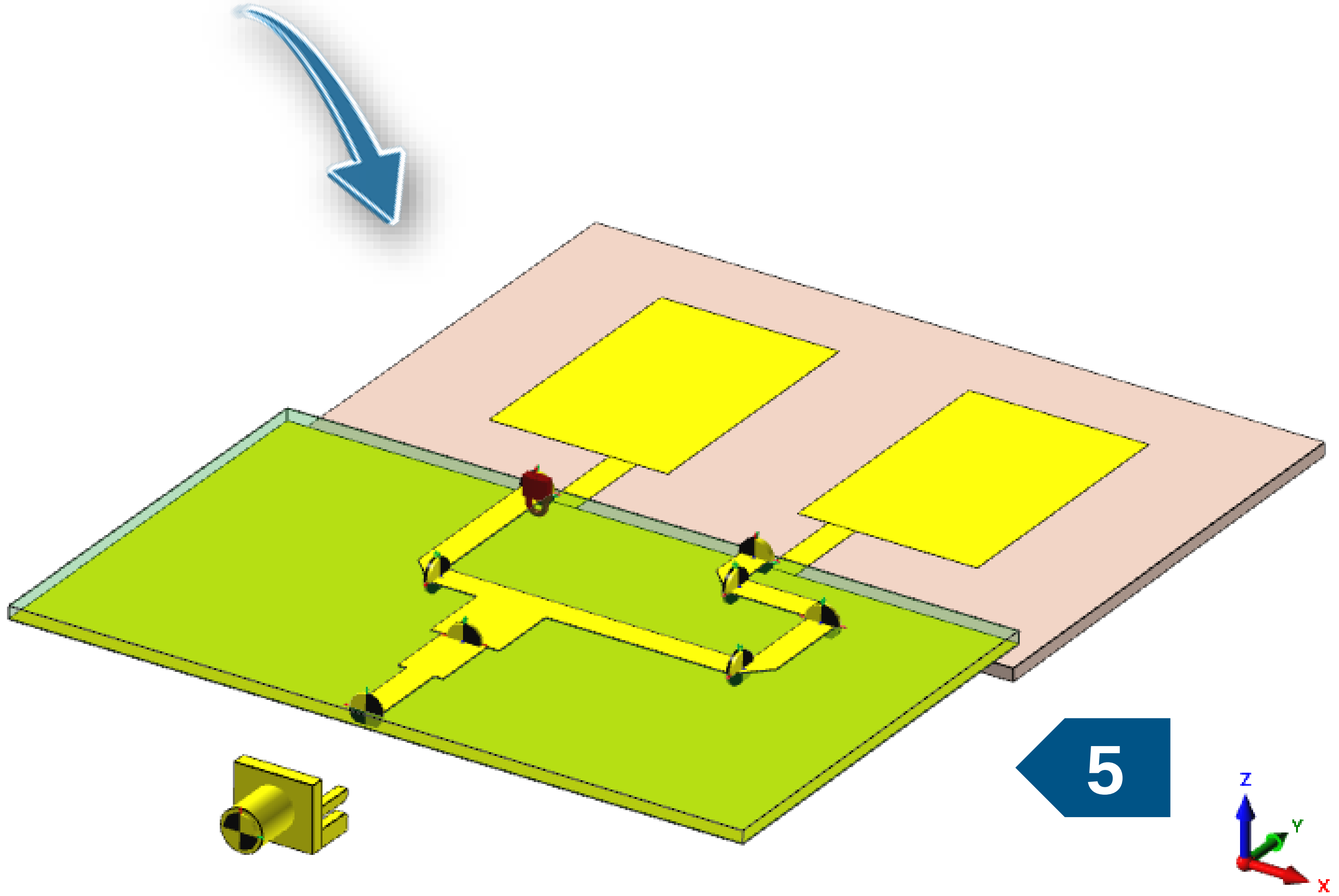
4

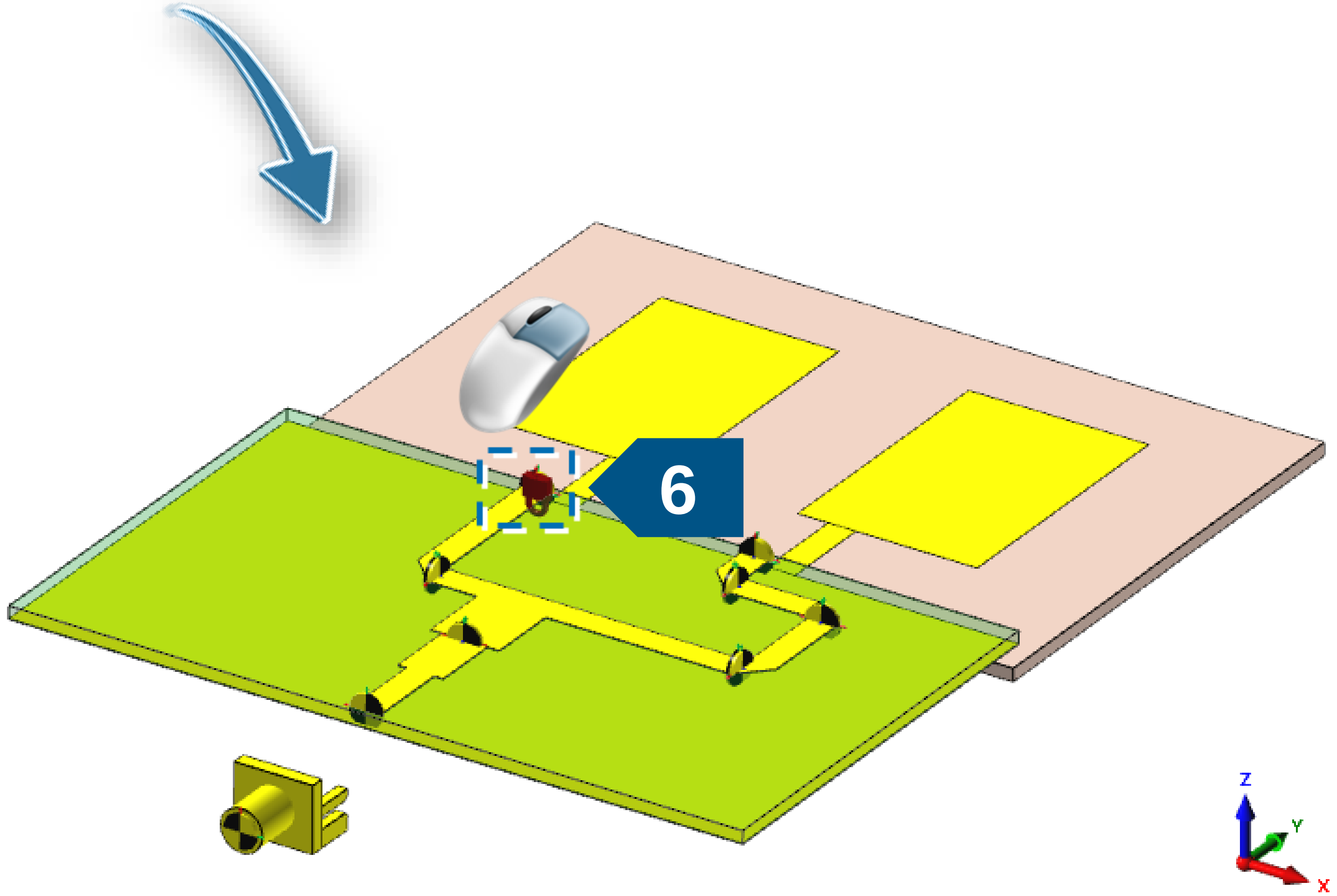


Block alignment in the Assembly View (3/7)

5. Press TAB to rotate feeding network in the right orientation.

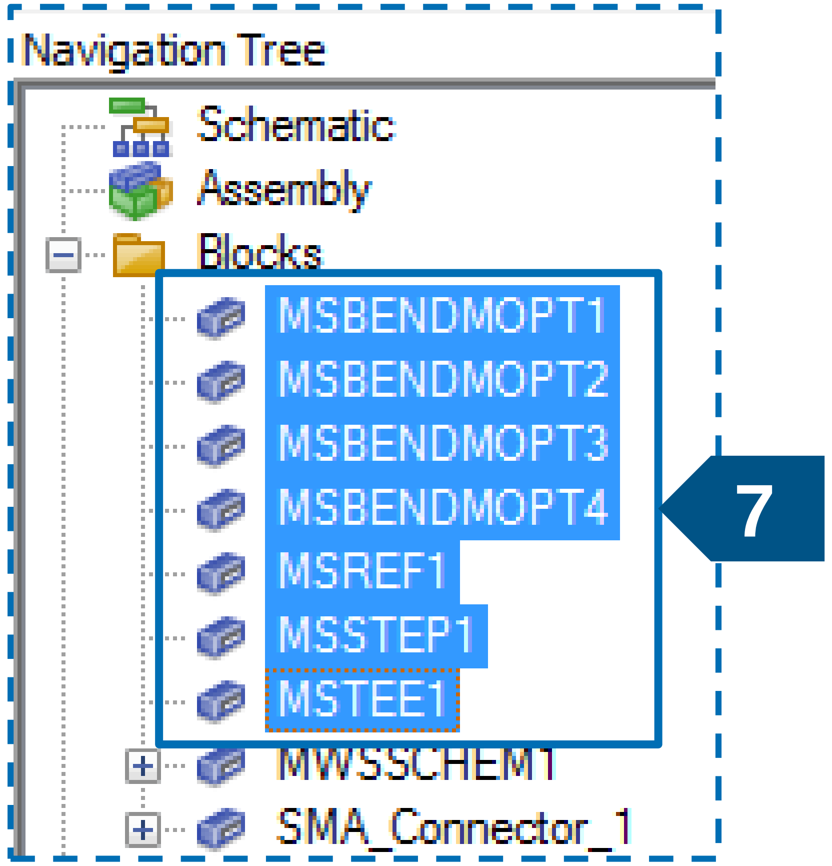
6. Remove the red lock in the context menu (right mouse button click).



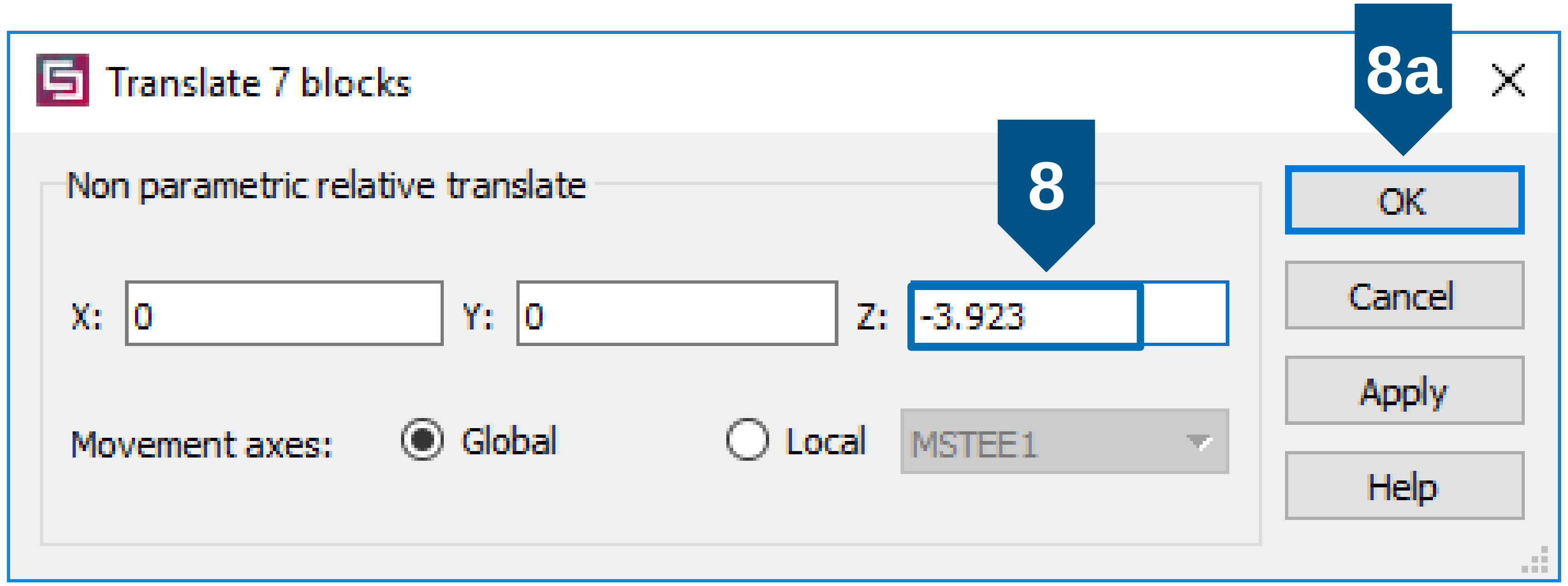


Block alignment in the Assembly View (4/7)

7. Select all 2D microstrip blocks from Navigation Tree.

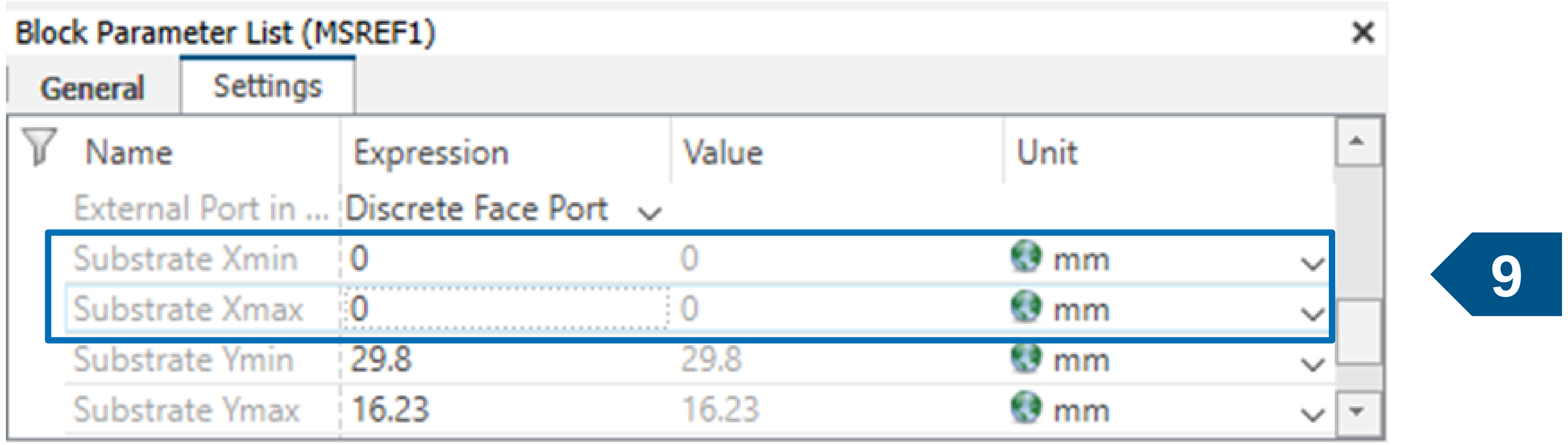


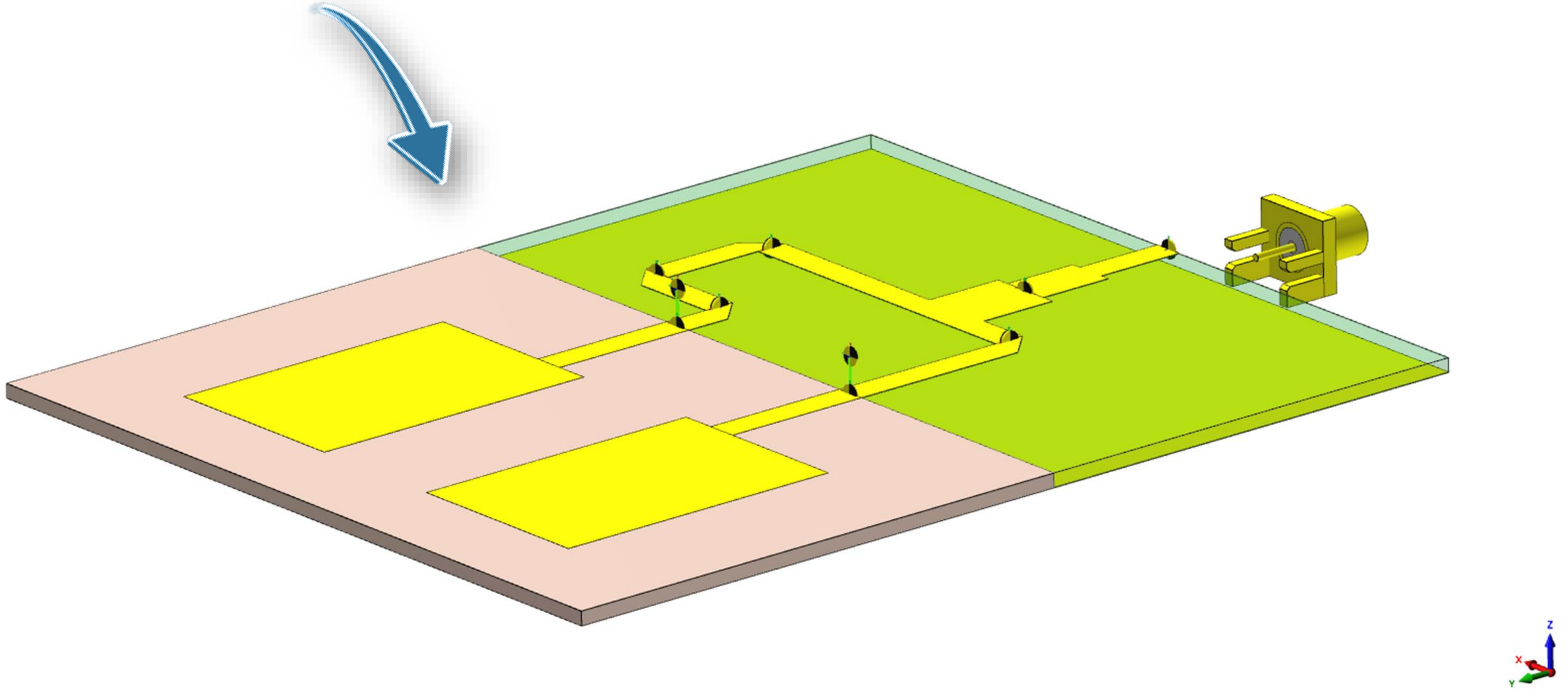
8. Translate MS blocks (hotkey T) along Z axis.
    a. Press OK to perform the operation.



Block alignment in the Assembly View (5/7)

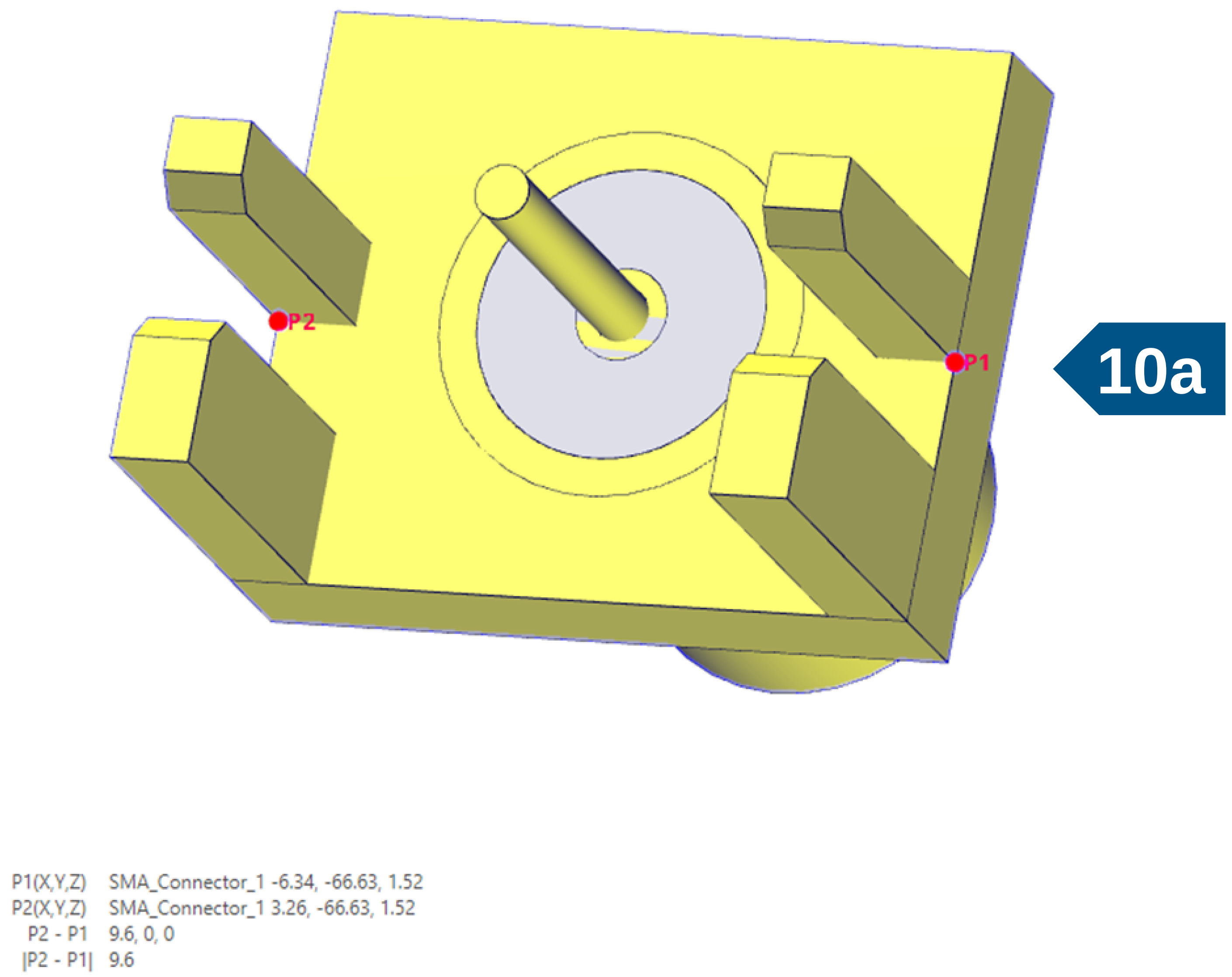
9. Adjust the substrate extension to 0 mm in X direction (MSREF1 block) .

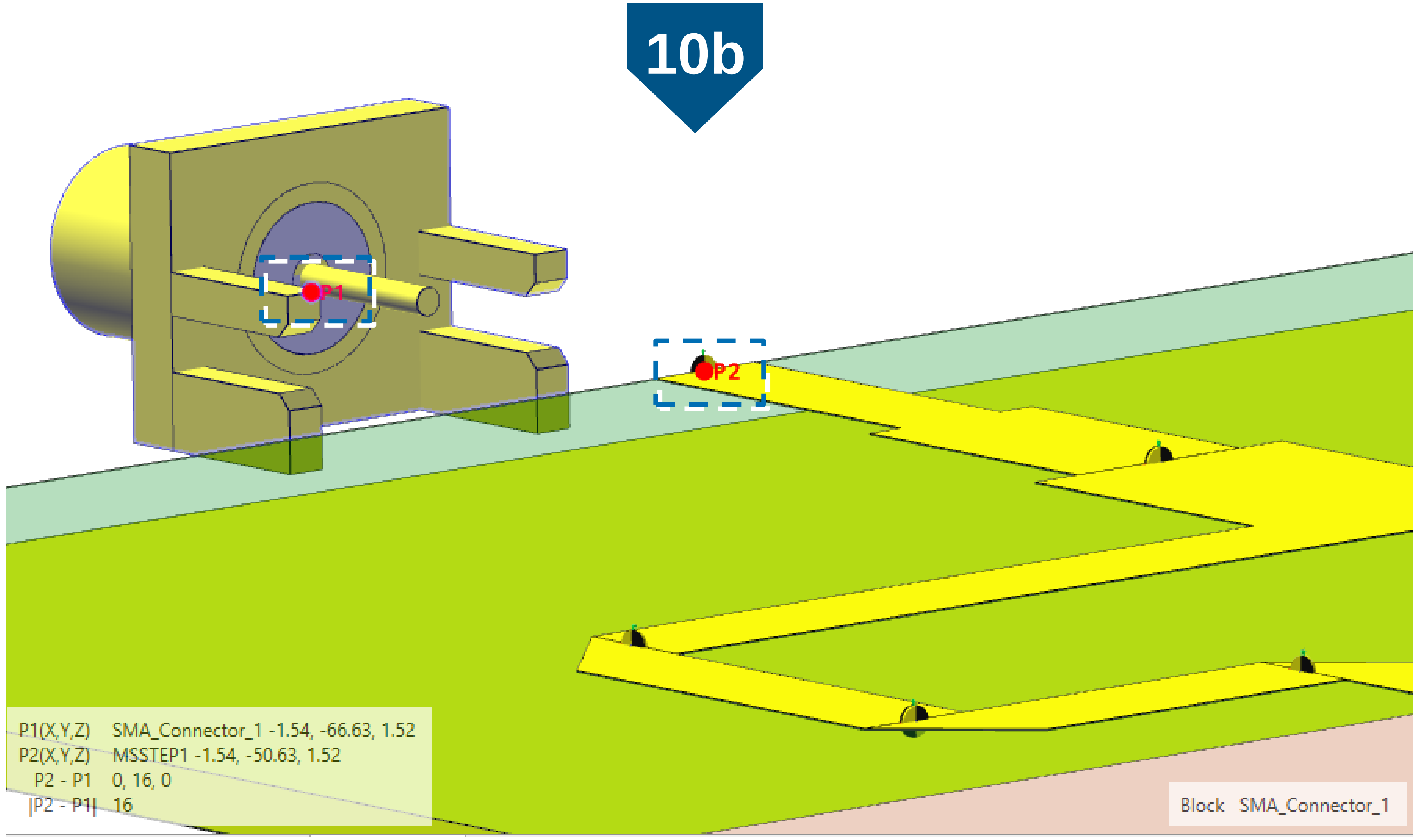




Block alignment in the Assembly View (6/7)

10. Pick Points (Hotkey P).
    a. Select P1 and P2 and apply mean operation to get P1 at SMA connector.
    b. Select P2 as the bottom edge center of MSTEP1.

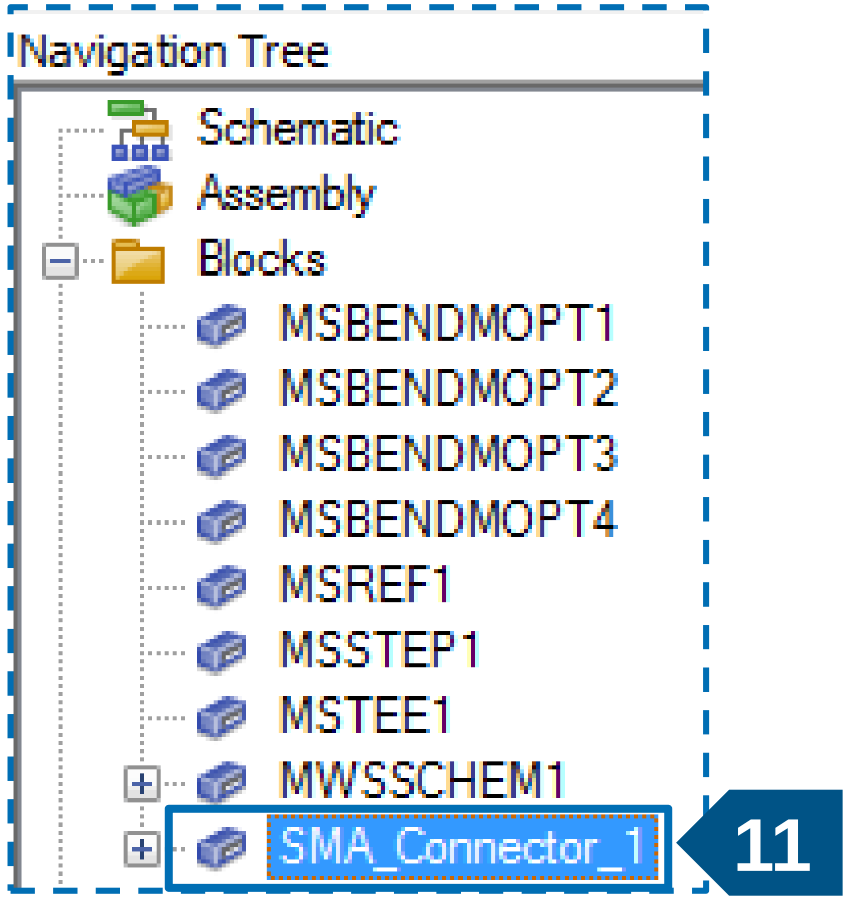


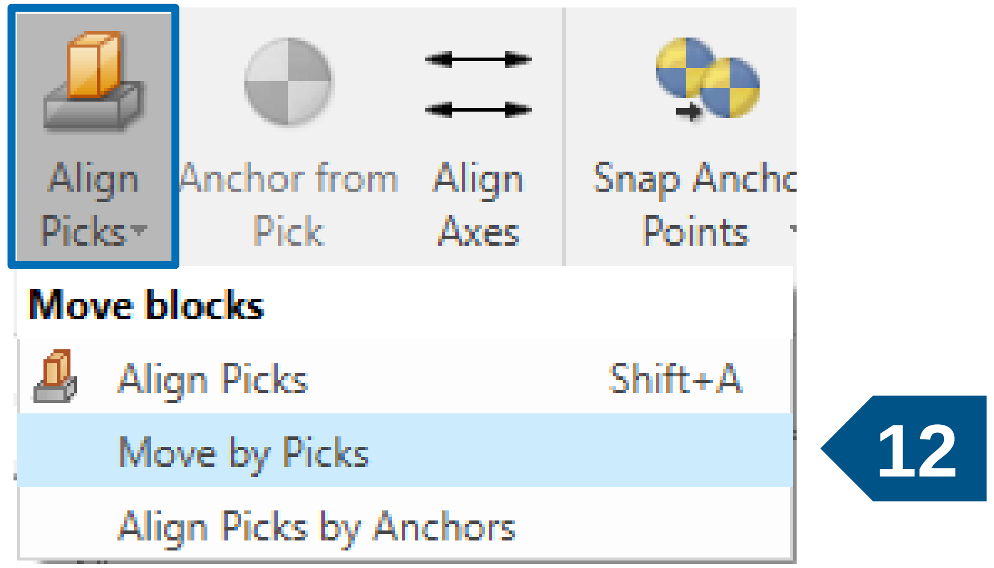


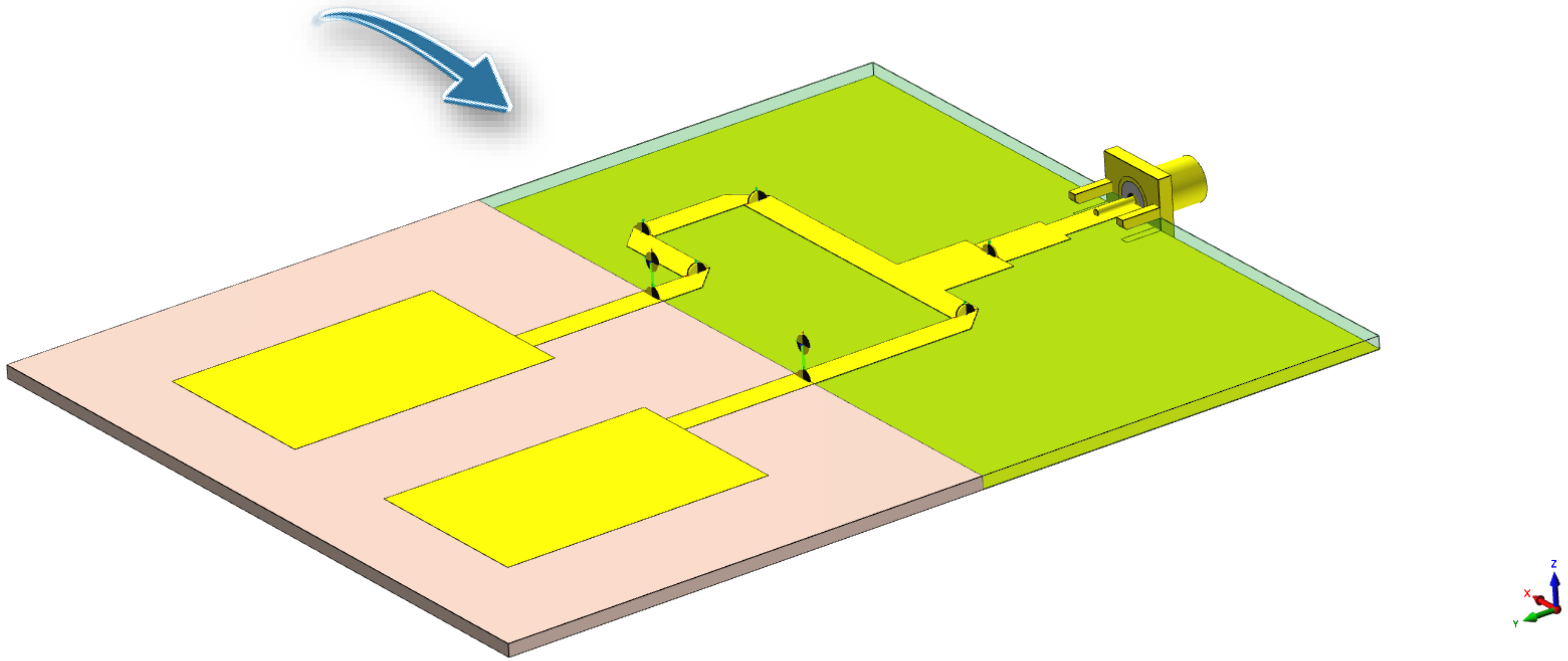
Block alignment in the Assembly View (7/7)

11. Select **SMA_Connector_1**.

12. Translate connector using **Move by Picks**.

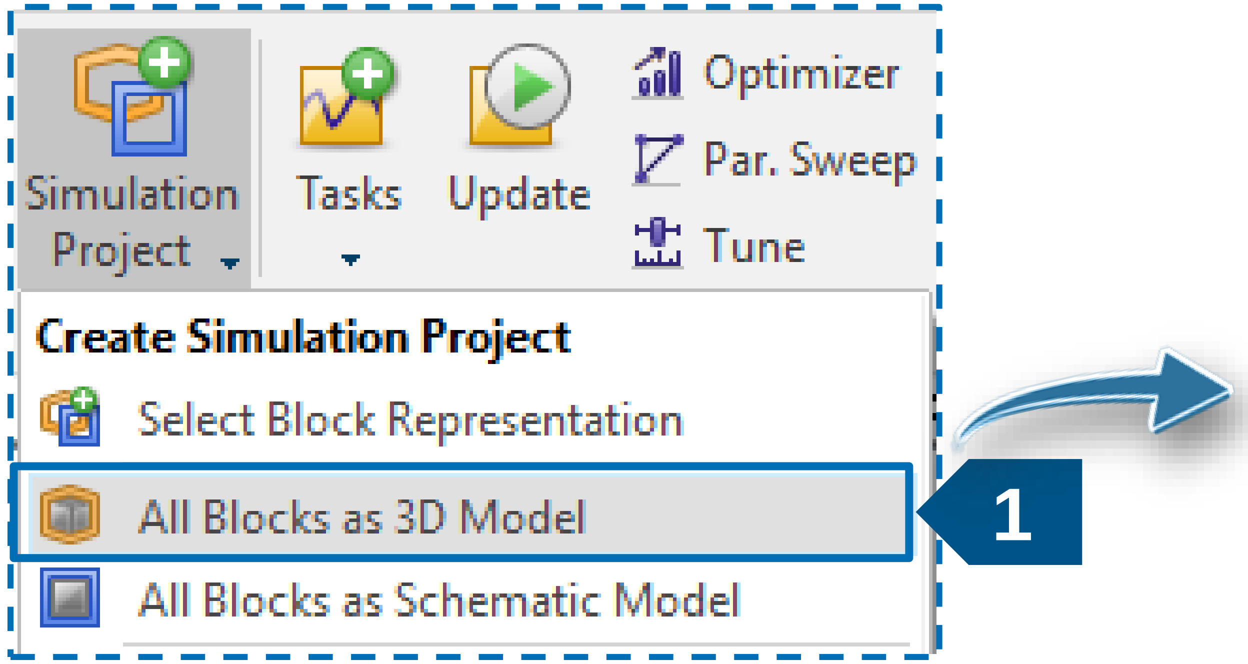


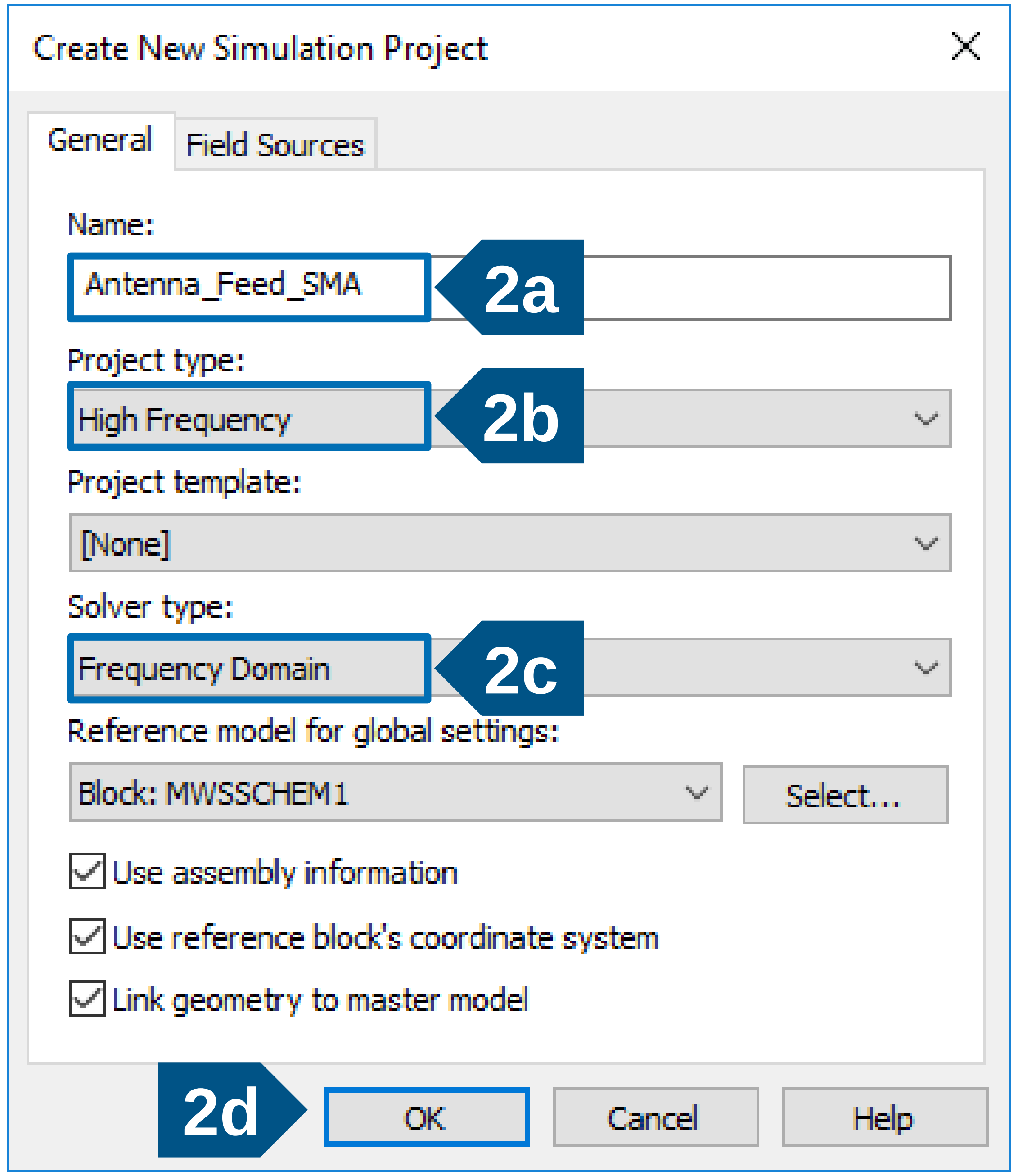




Create 3D Simulation Project

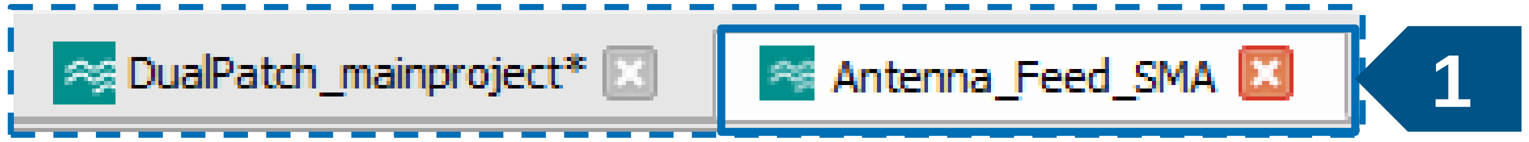
1. Use the command **“All Blocks as 3D Model”** to select automatically all blocks included in the Assembly and create a new Simulation Project.
2. Setup Simulation Project.
    a. Name it as **“Antenna_Feed_SMA”**.
    b. Select **High Frequency**.
    c. Set the **Frequency Domain** as solver type.
    d. Press OK to create the project.



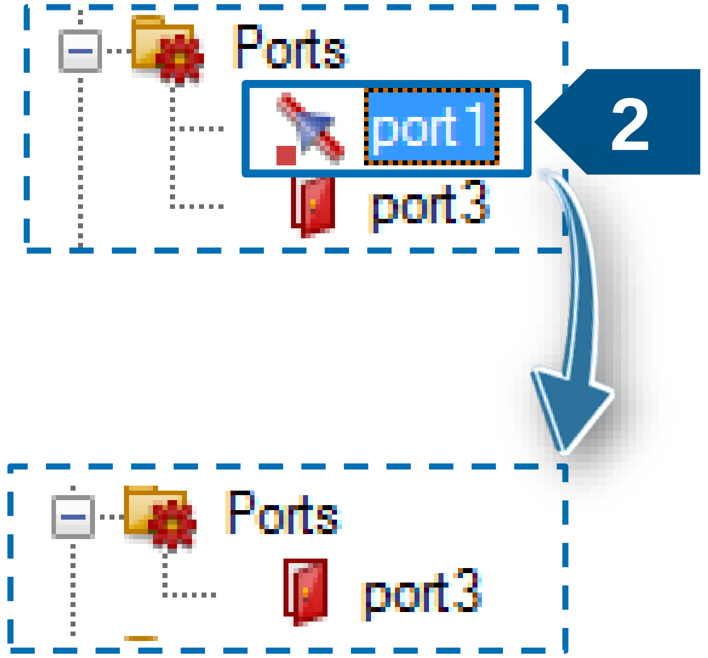


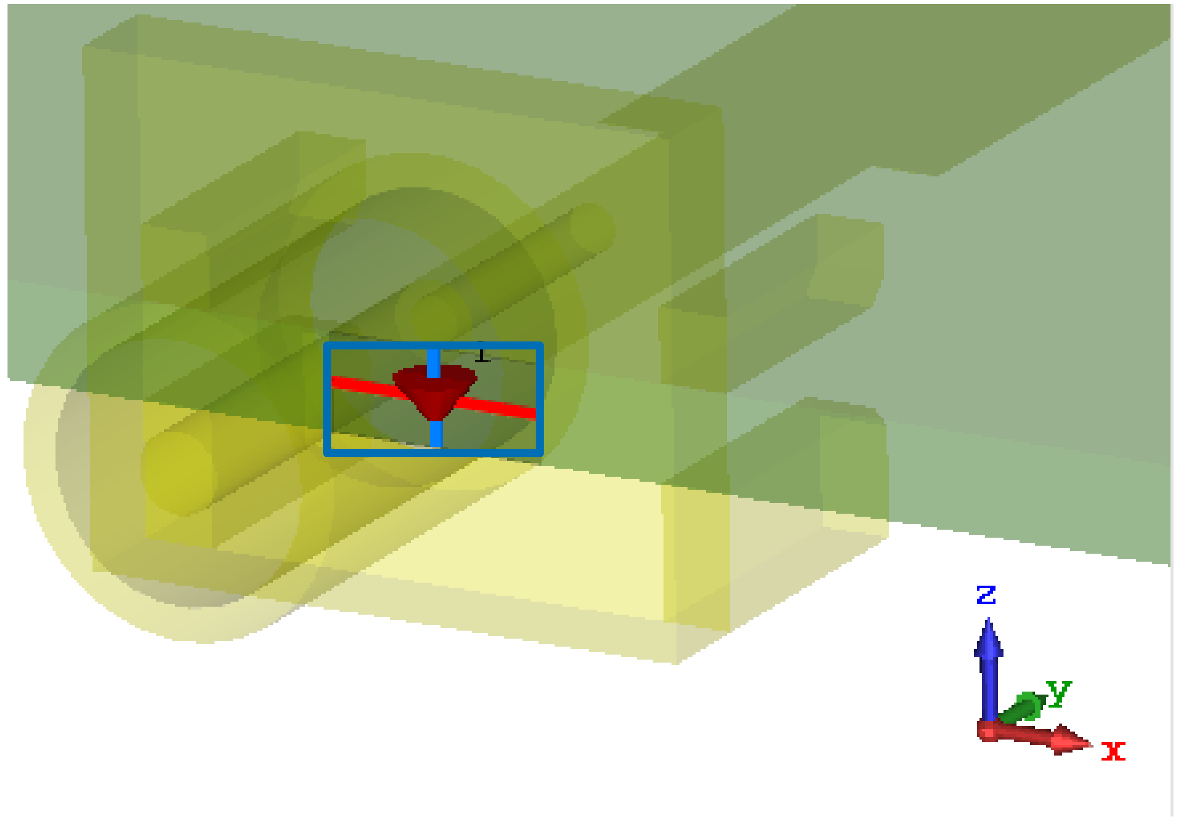
Modify Simulation Project (1/3)

1. Select newly created Simulation Project.



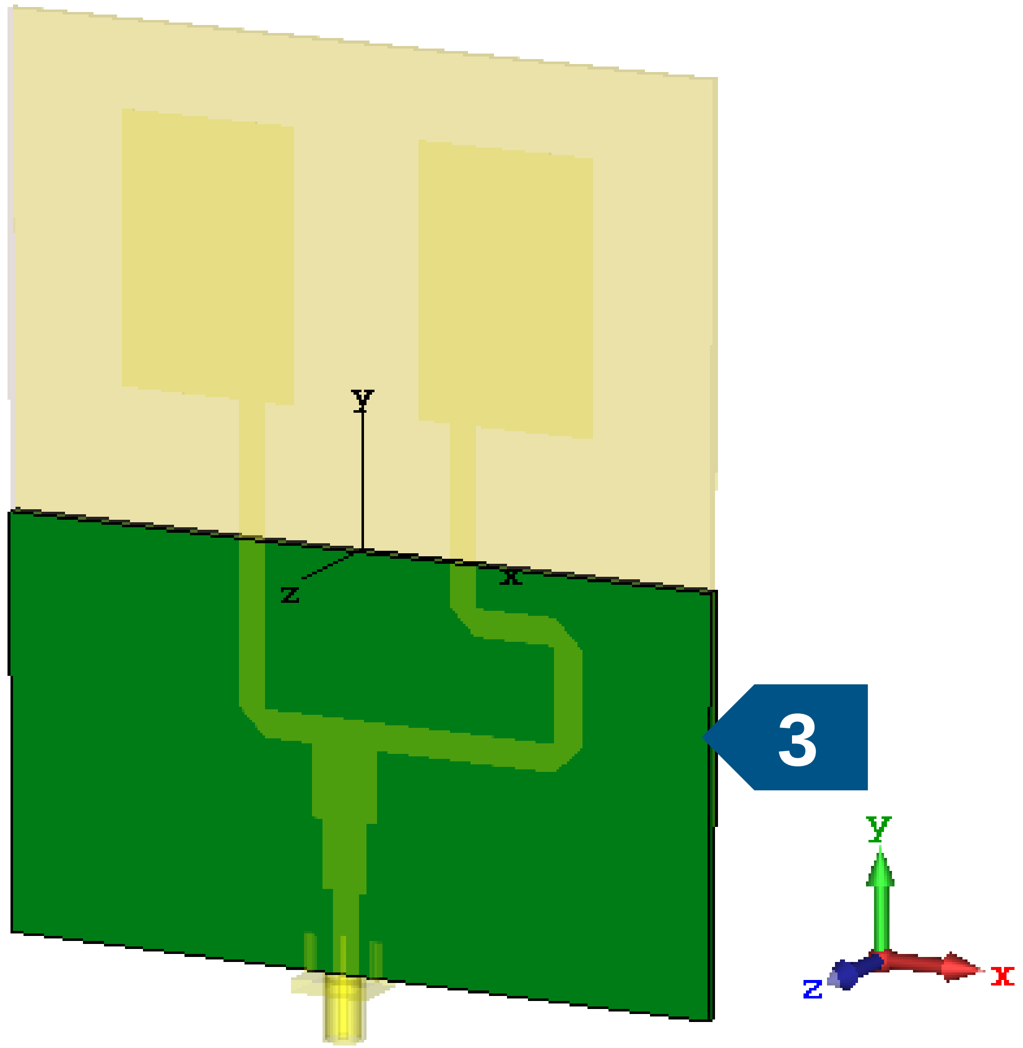
2. Select & **DELETE** Discrete Face Port that has been automatically attached to MSTEP open end.

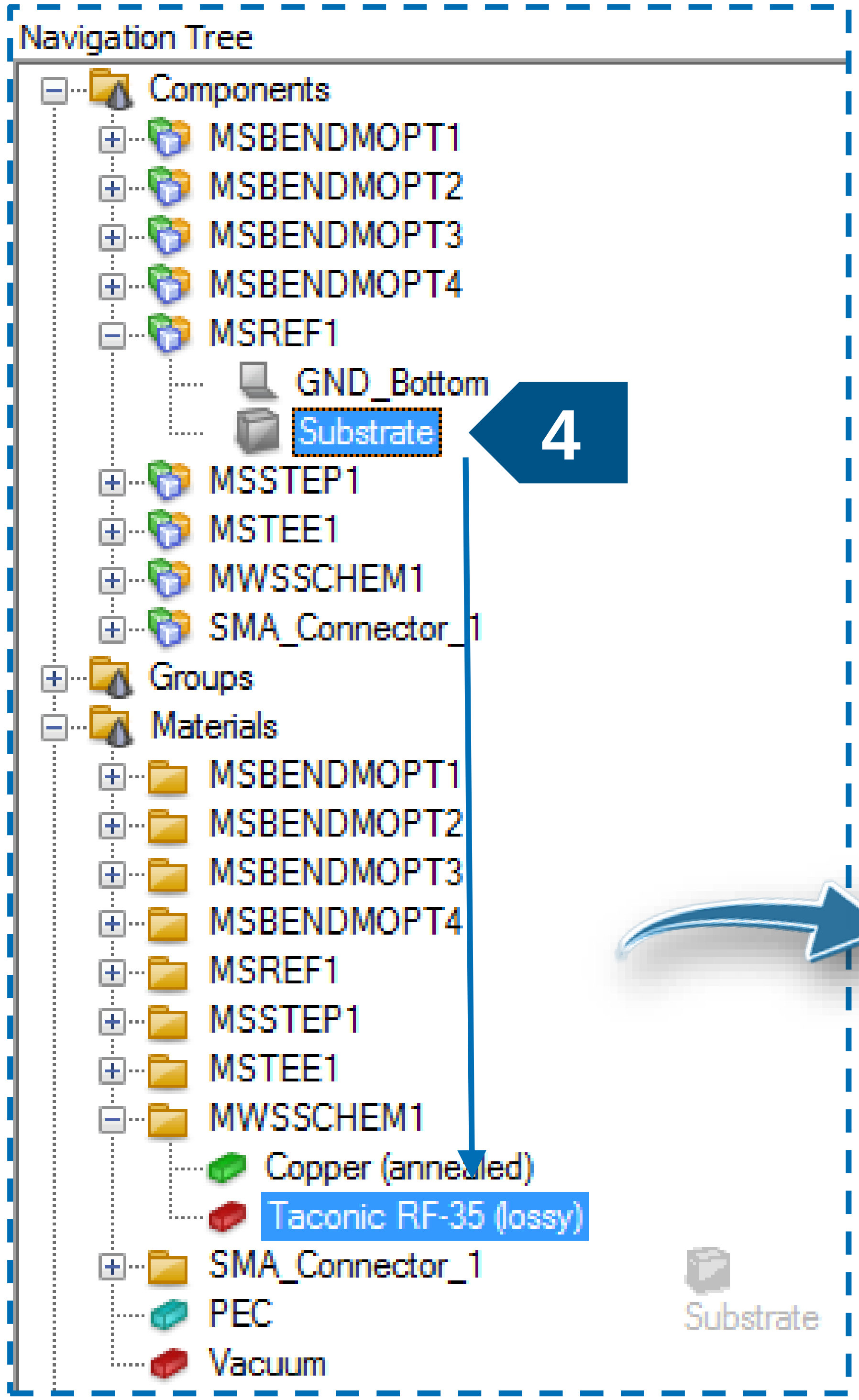


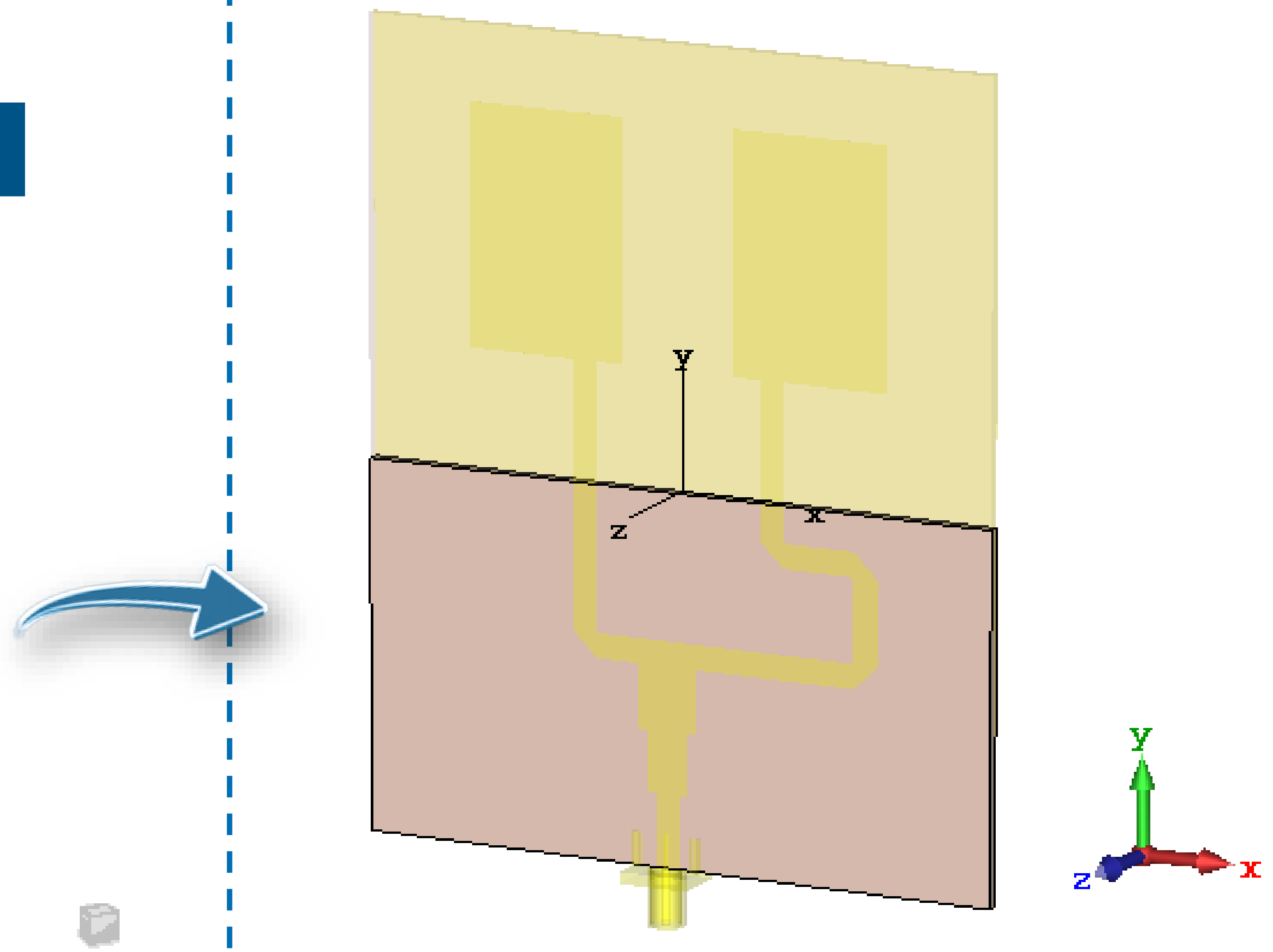


Modify Simulation Project (2/3)

3. Select MSREF1 from Navigation Tree or via double click on the model.
4. Drag & Drop MSREF1/**Substrate** on to MWSSCHEM1/**Taconic RF-35 (lossy).**

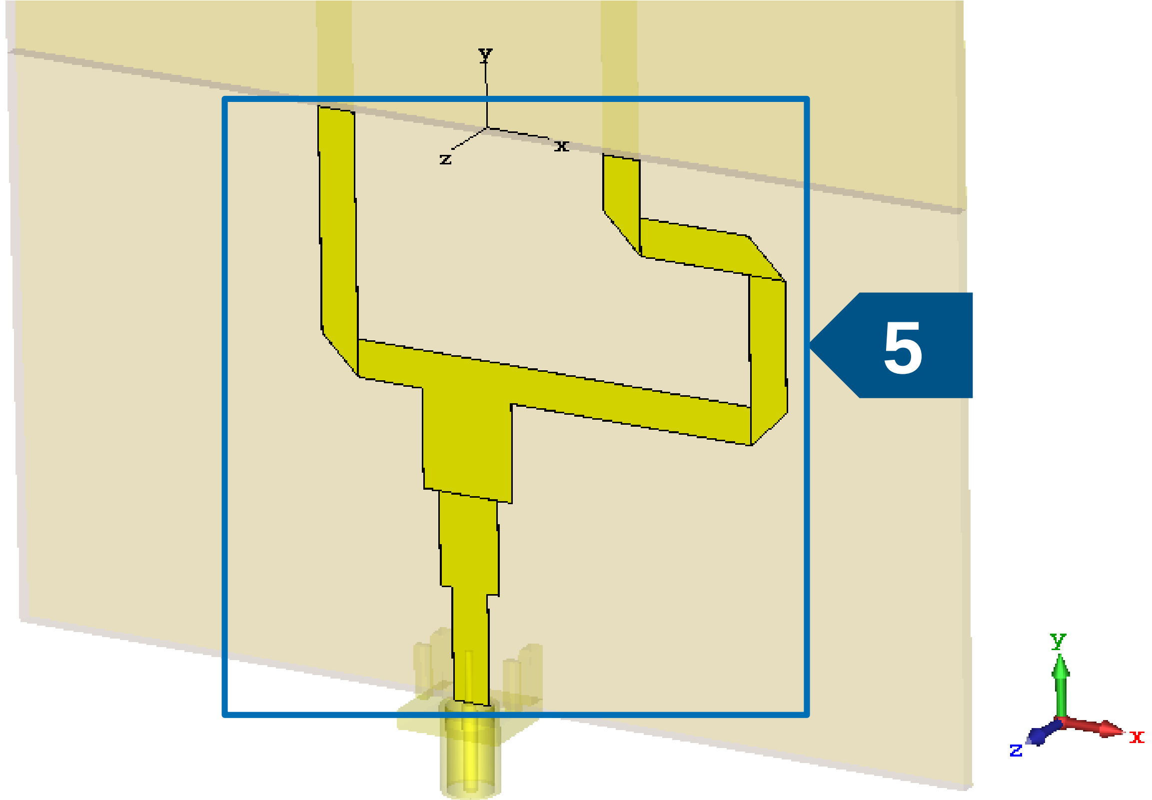




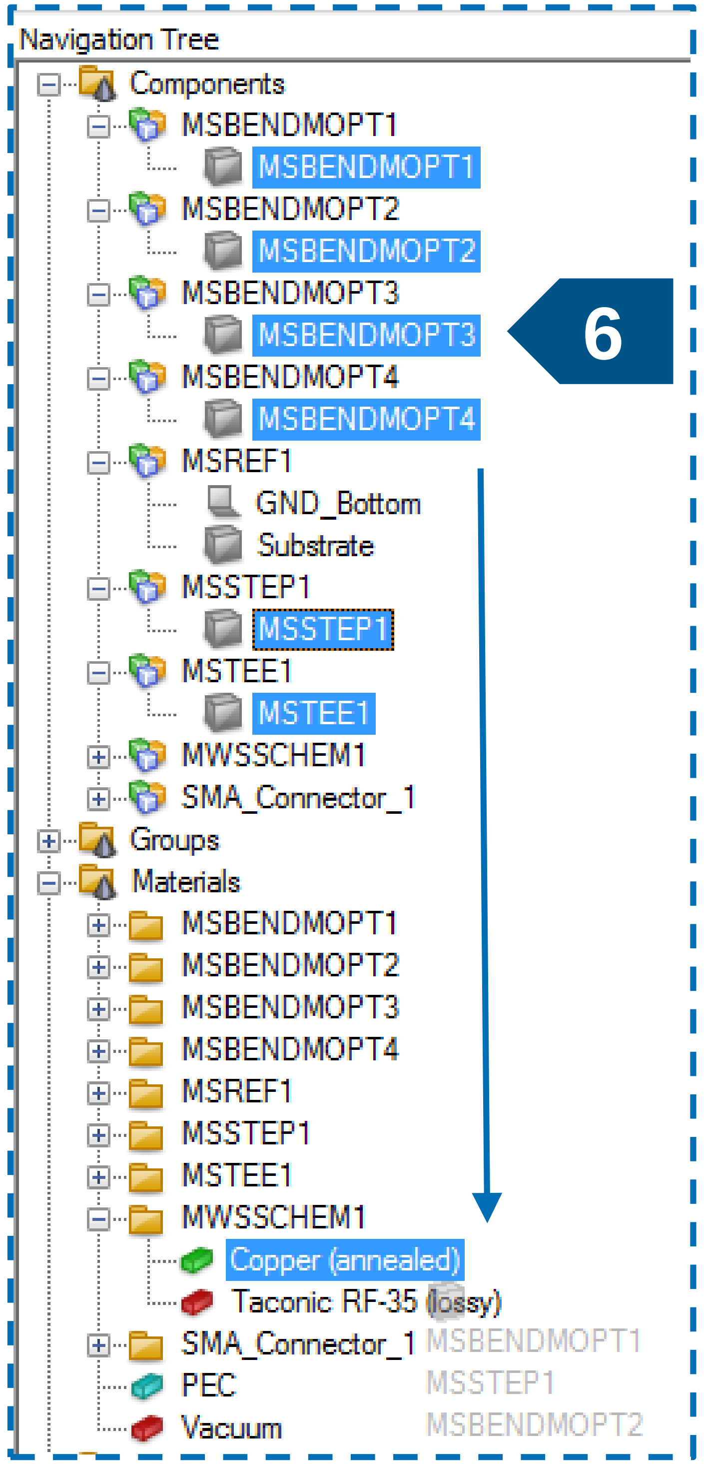


Modify Simulation Project (3/3)

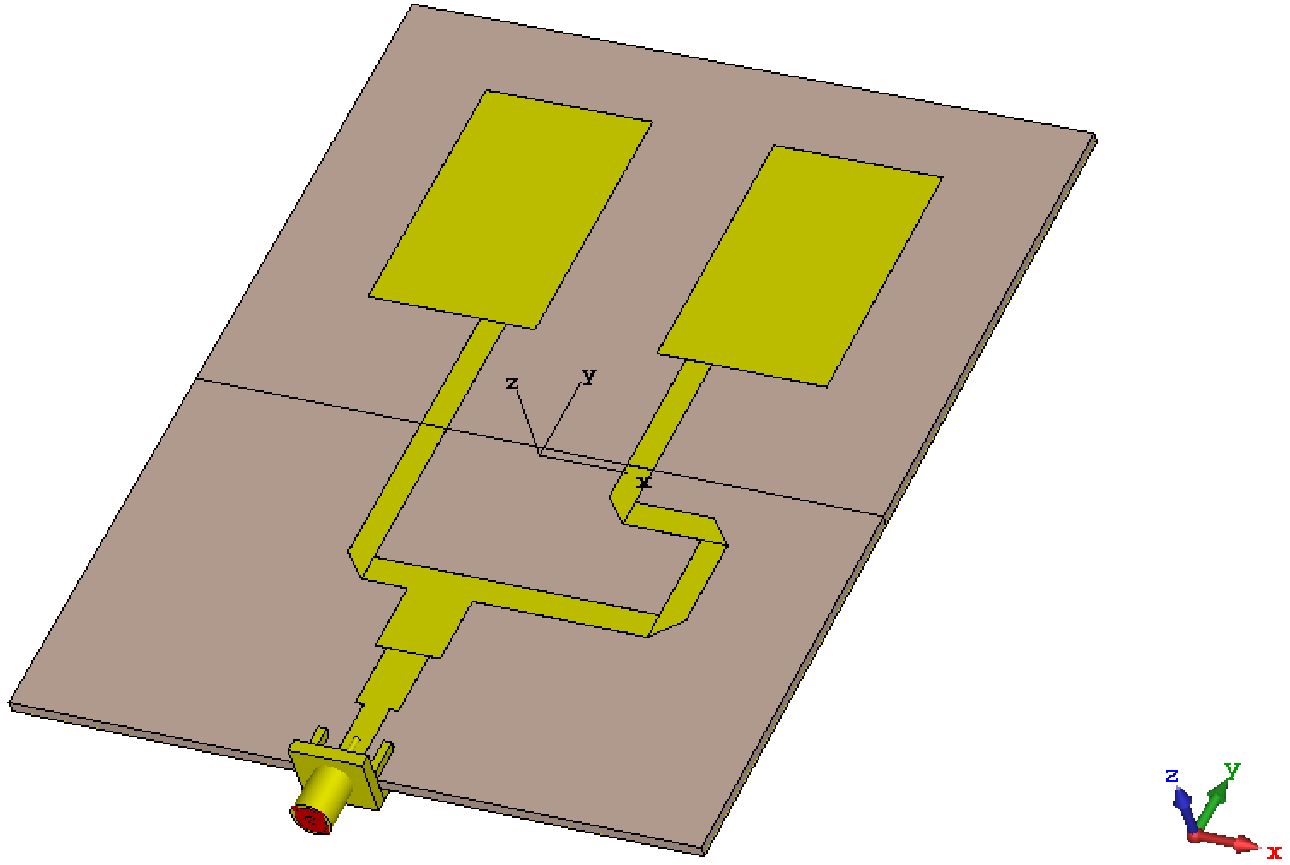
5. Multiple select all highlighted microstrips (6 traces) on the model.
6. Drag & Drop **selected MS parts** on to MWSSCHEM1/**Copper (annealed).**



5

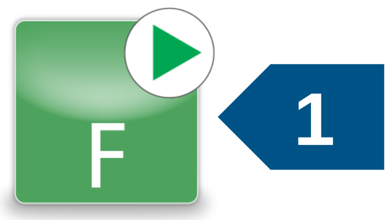


6



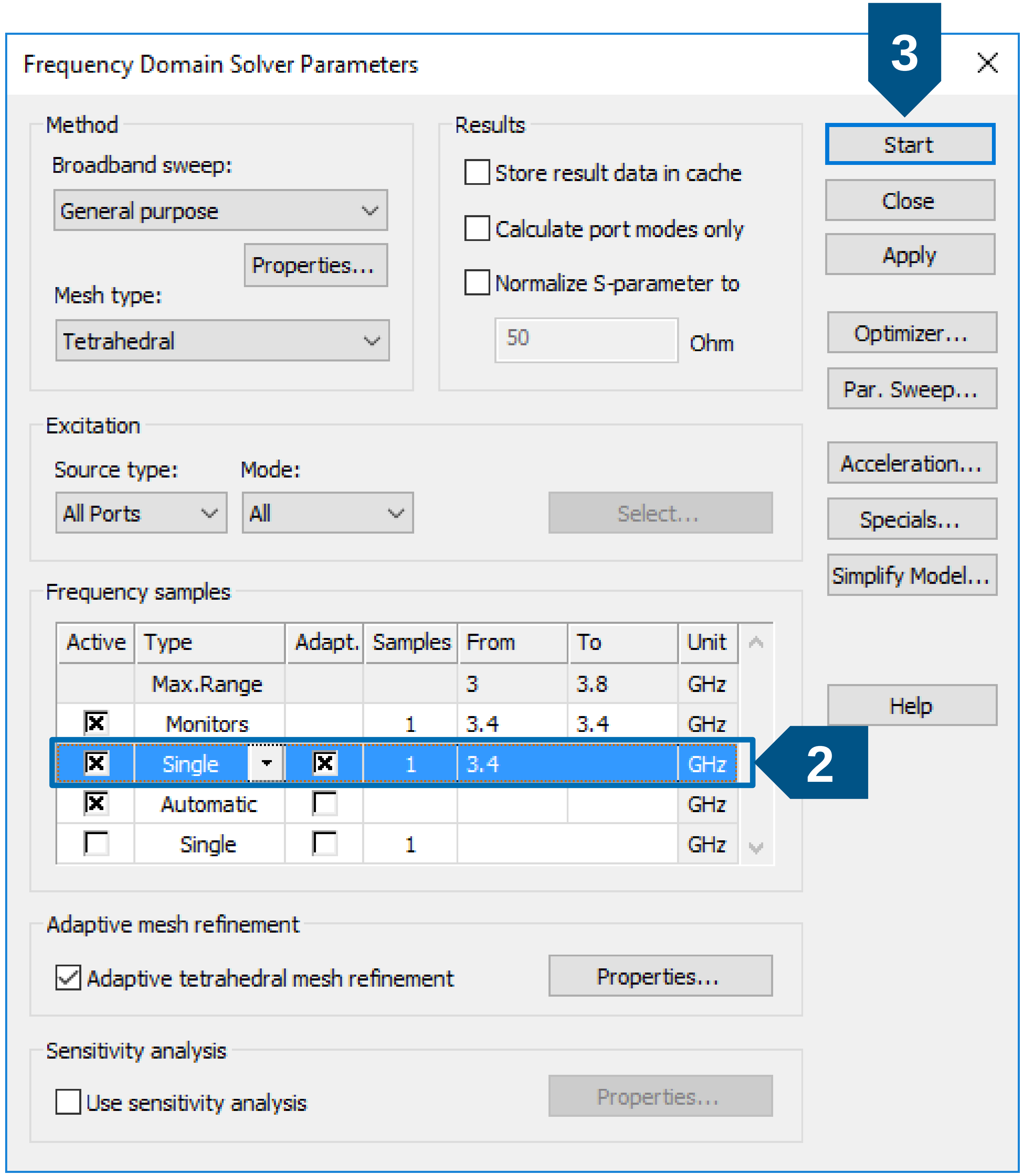
Setup Frequency Domain Solver

1. Open Frequency Domain Solver dialog box.



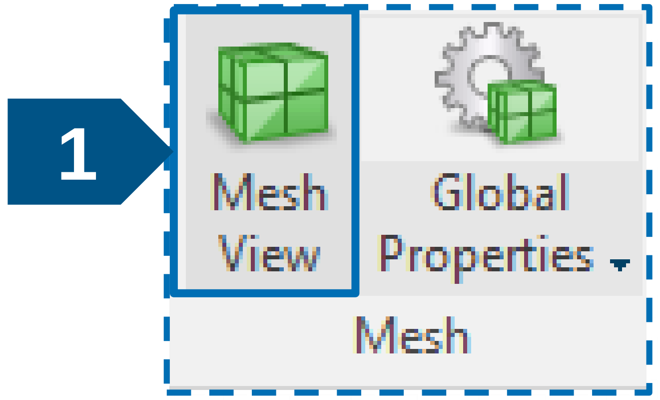
2. Set **Adaptive Meshing Frequency @ 3.4 GHz.**

3. Start Simulation.

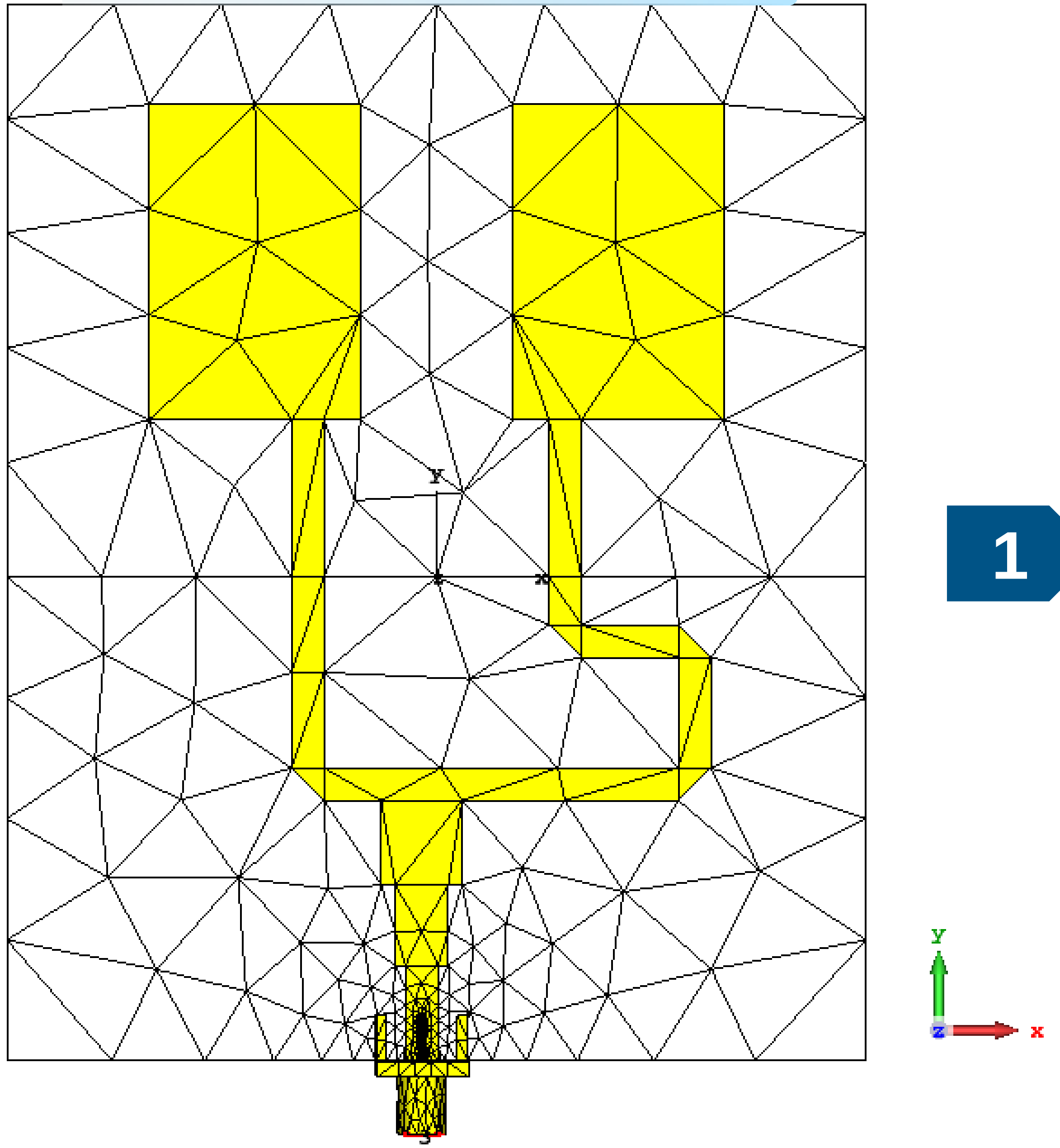


View Final Refined Mesh

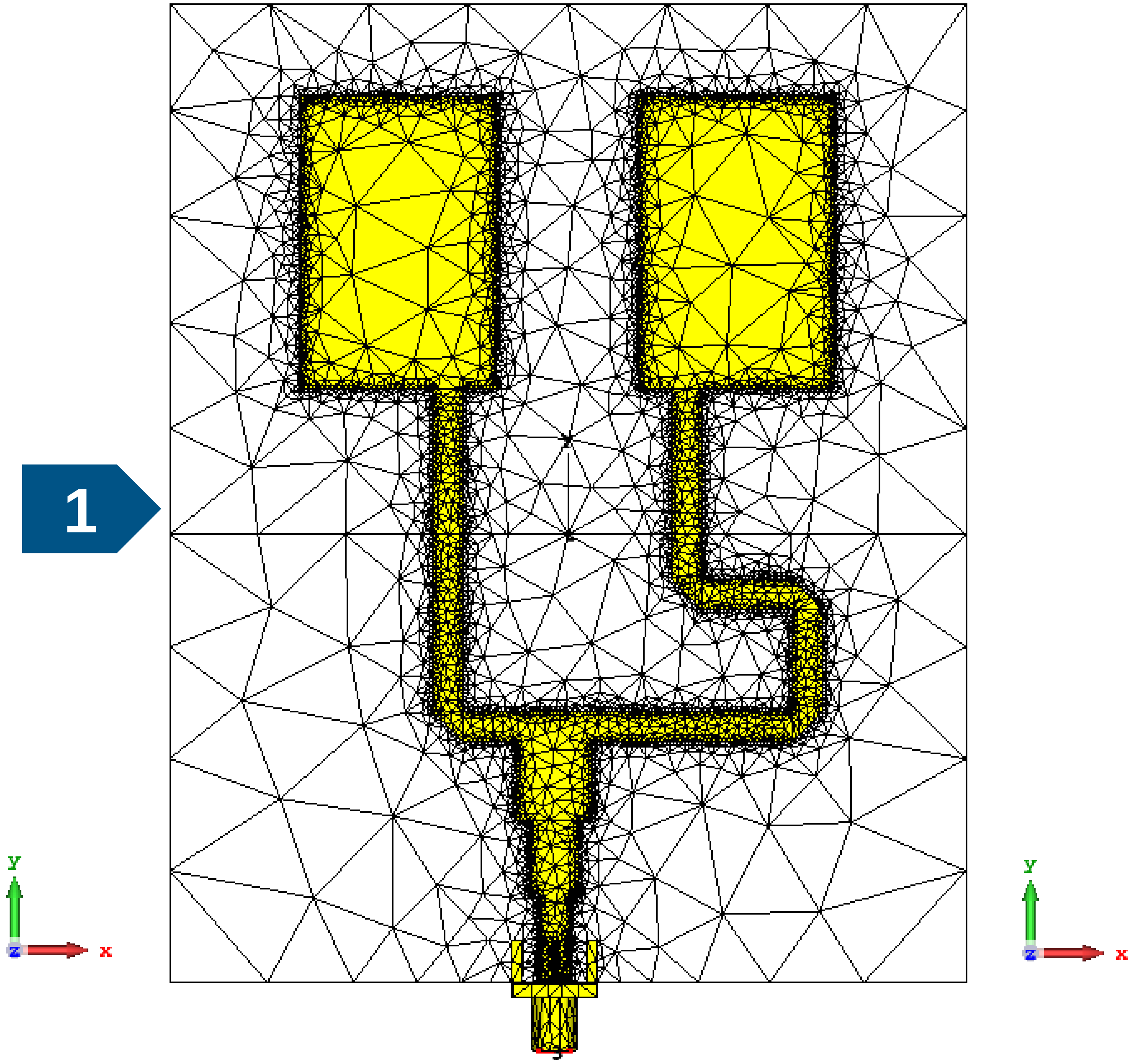
1. Enable Mesh View.



Initial Mesh



Refined Mesh

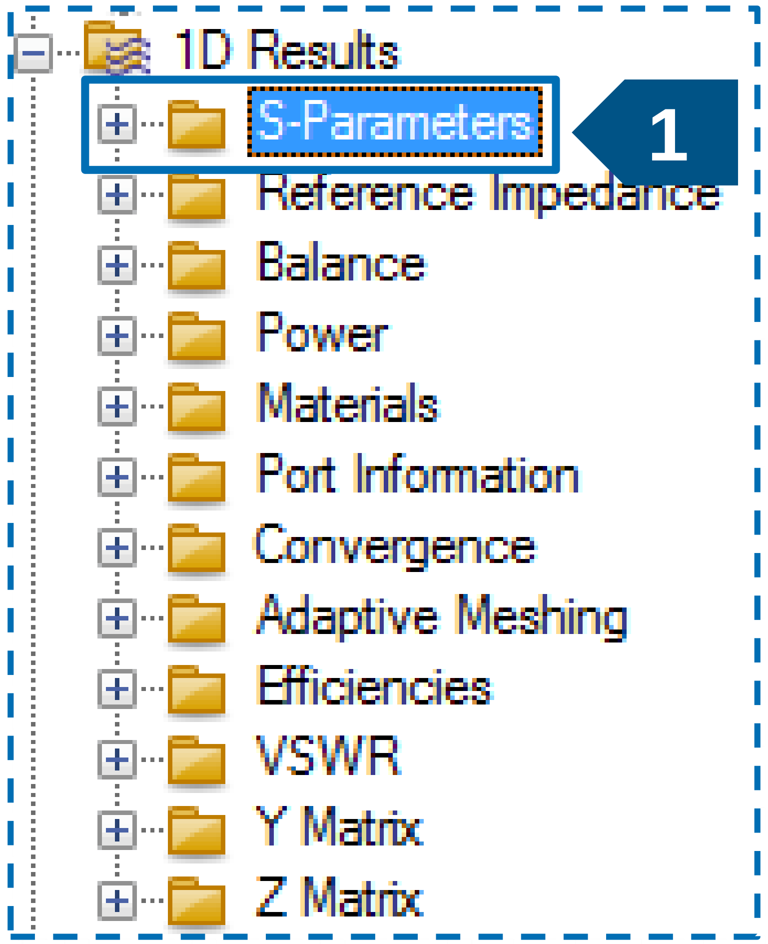


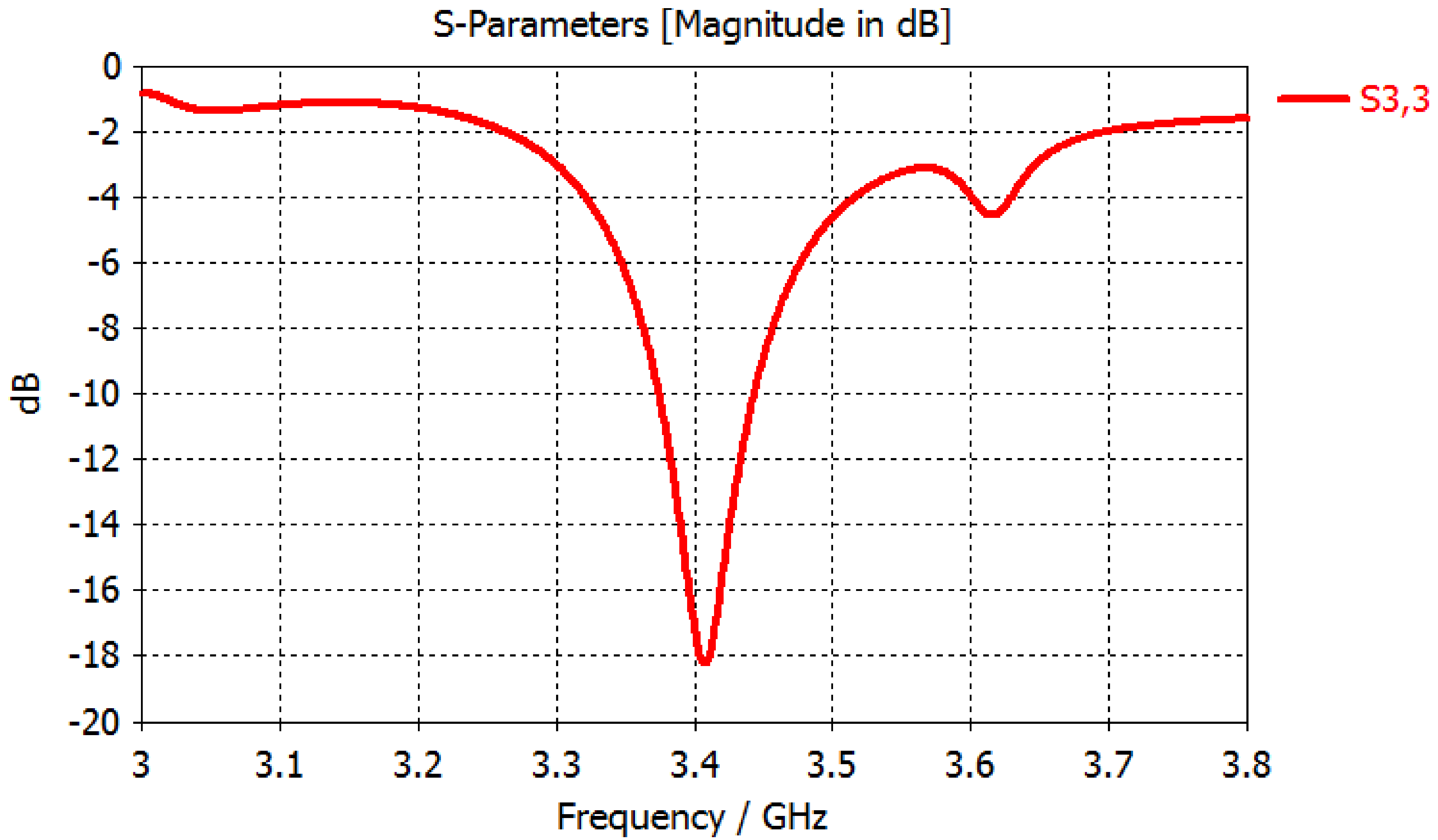
It's very important to fix the adaptive meshing frequency around the antenna operating frequency.

The mesh is automatically refined around the metallic edges where the field is concentrated.

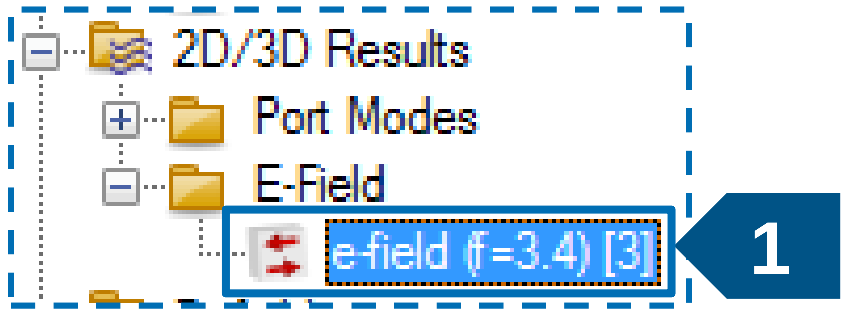
View S-Parameters

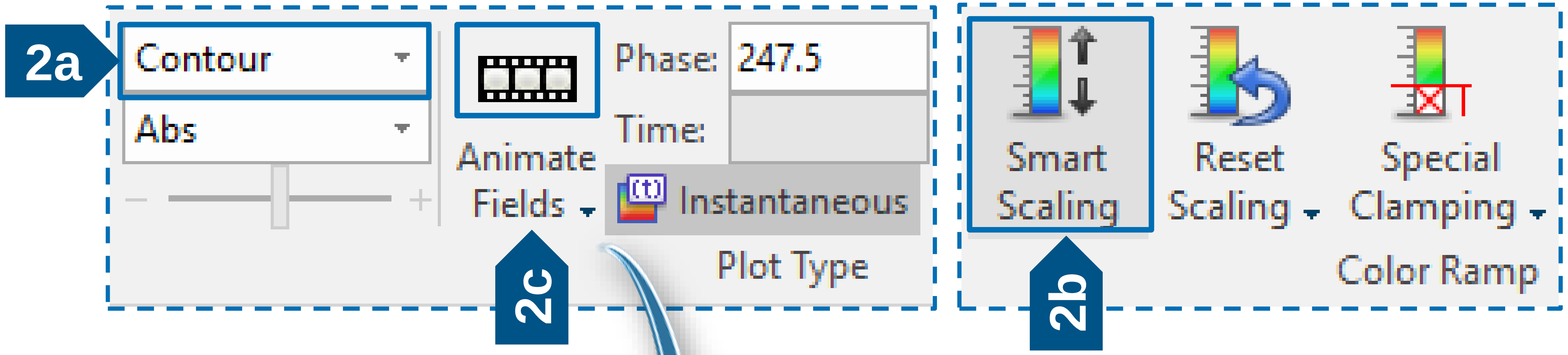
1. Select S-Paramters folder to check antenna matching, this time including the 3D feeding network and the connector.

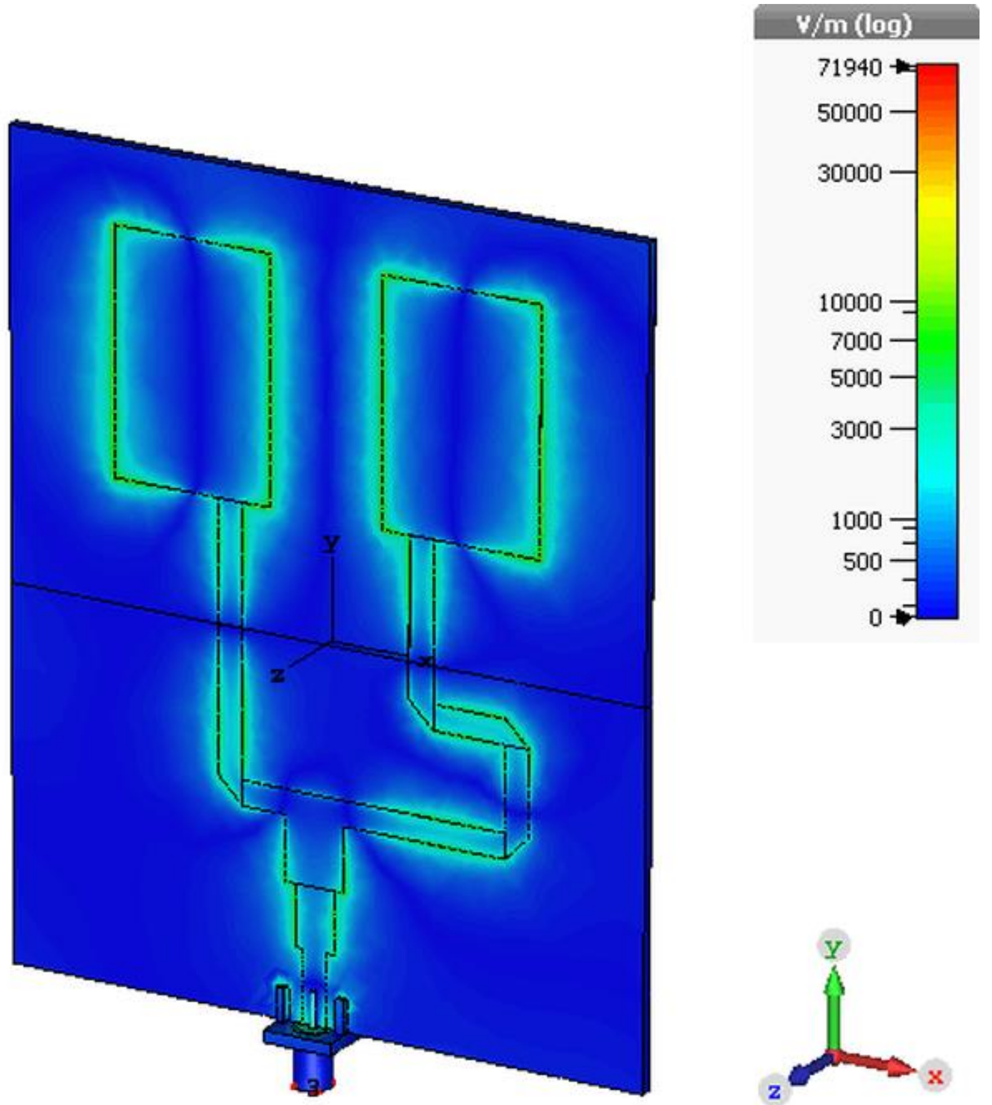




View 2D/3D Results





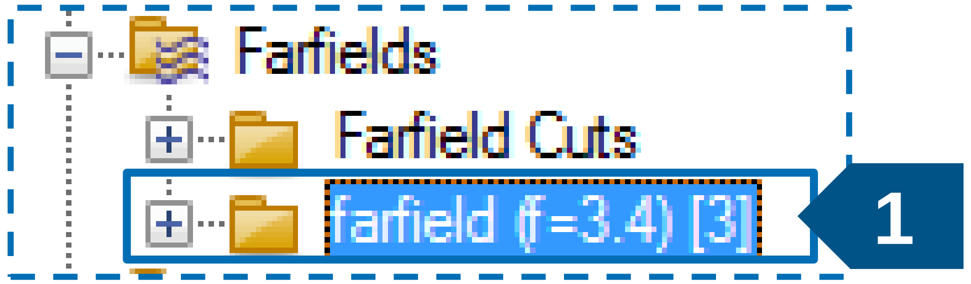


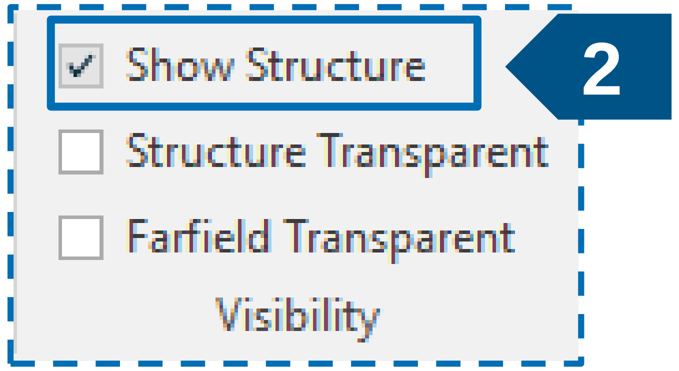
1. Select **E-Field > e-field (f=3.4)[3]**.

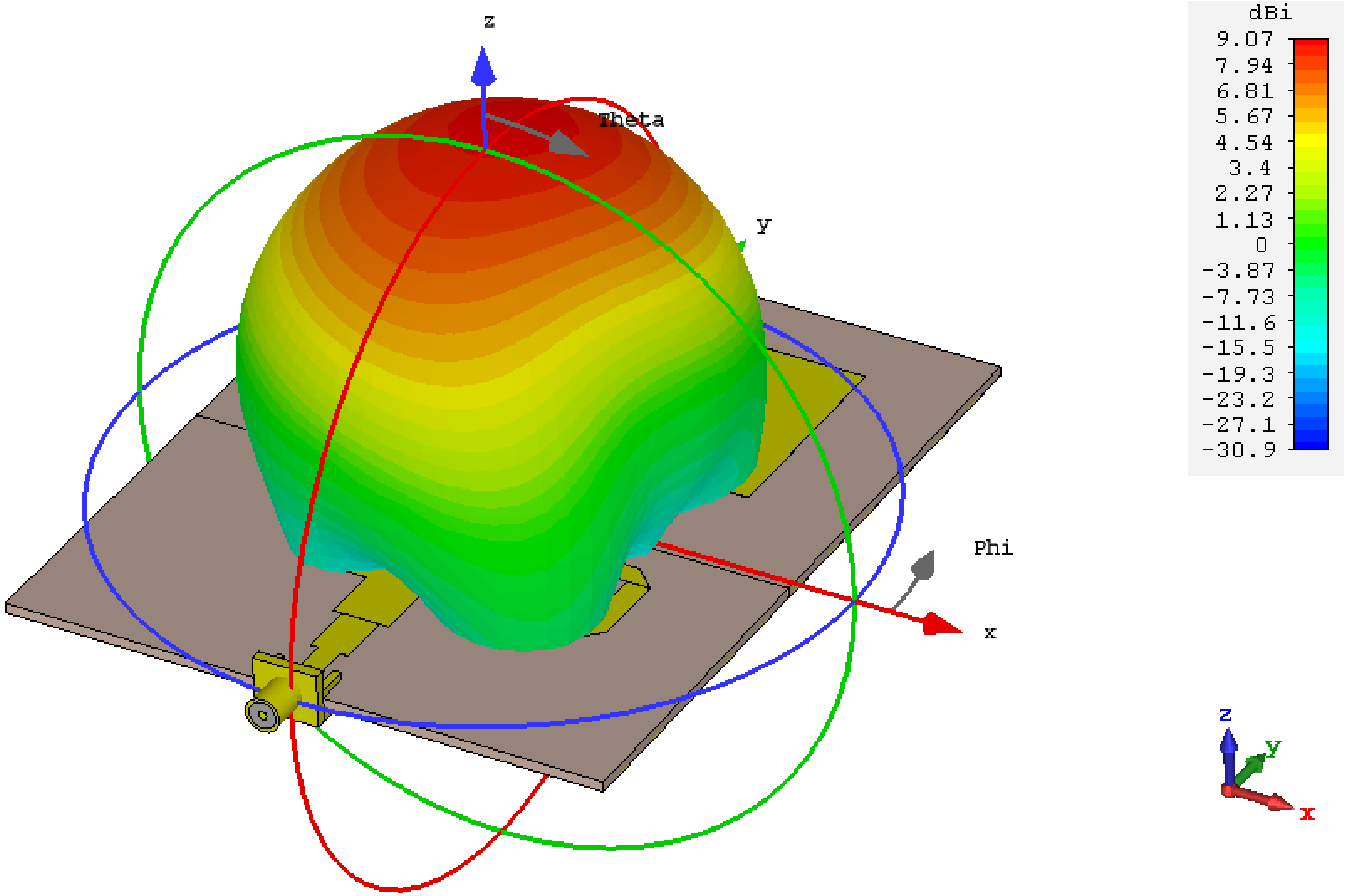
2. Specify field plot settings.
   a. Set Contour plot.
   b. Apply Smart Scaling.
   c. Animate Fields.

View Farfield Results

1. Select **Farfields > farfield (f=3.4)[3]**.
2. Enable "**Show Structure**" in the farfield ribbon to overlay the geometry on to the farfield plot.







farfield (f=3.4) [3]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Directivity
Frequency	3.4 GHz
Rad. effic.	-0.4677 dB
Tot. effic.	-0.5530 dB
Dir.	9.075 dBi