SUSTech Southern University of Science and Technology

Microwave Engineering (Lab)

Lab 6: Design of branch line coupler

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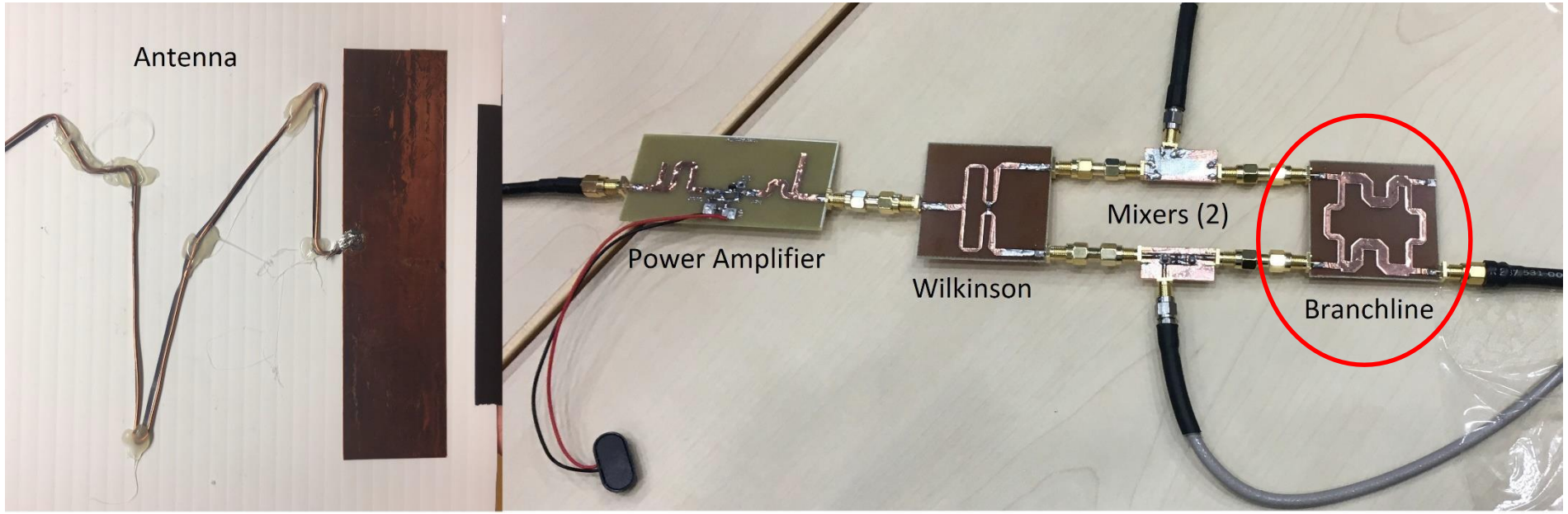
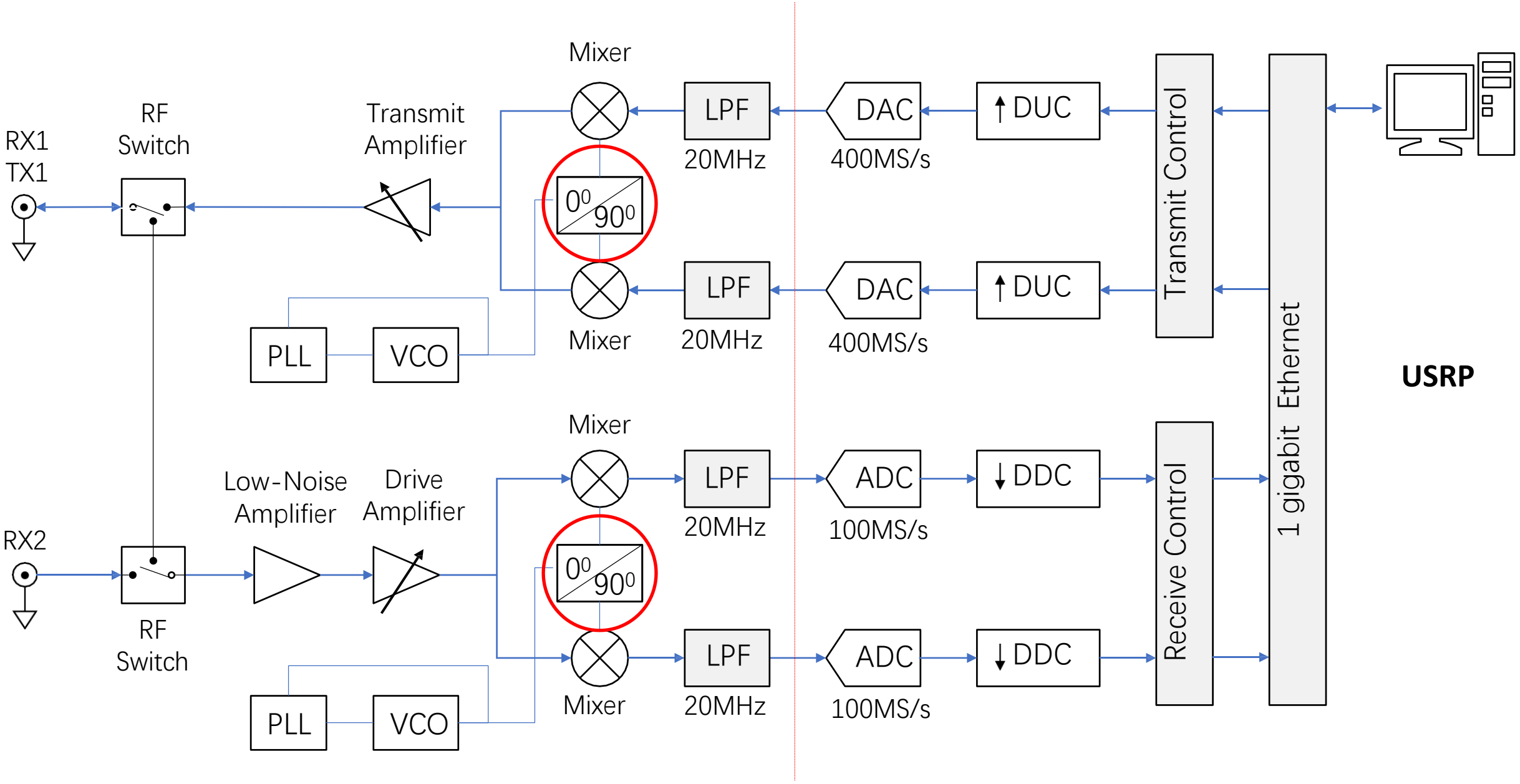
Tencent Meeting: 874-068-9694

Bits2Waves, a 1-day experience on building your own modern digital radio.



https://rickettslab.org/bits2waves/bits2waves-download/


RX1
TX1
RF
Switch
Transmit
Amplifier
Mixer
LPF
20MHz
DAC
400MS/s
DUC
Transmit Control
1 gigabit Ethernet
USRP
0⁰
90⁰
PLL
VCO
Mixer
LPF
20MHz
DAC
400MS/s
DUC
RX2
Low-Noise
Amplifier
Drive
Amplifier
RF
Switch
Mixer
LPF
20MHz
ADC
100MS/s
DDC
Receive Control
PLL
VCO
Mixer
LPF
20MHz
ADC
100MS/s
DDC

耦合器是一个四端口微波器件，通常将1-4端口分别指代输入端、直通端、耦合端和隔离端。大多数应用中大部分功率从直通端输出，耦合端则输出一小部分功率，以获得输入端信号的备份，隔离端无输出。如功率监控系统，测试仪器，正交功率分配。

3dB分支线定向耦合器：如果端口微带线的特性阻抗相等且为Z_0，竖直分支微带线特性阻抗也为Z_0，水平分支微带线特性阻抗取值为$Z_0/\sqrt{2}$，此时，直通输出口和耦合输出功率相等，均为输入端口的一半，且有90°的相位差，隔离端输出为0。

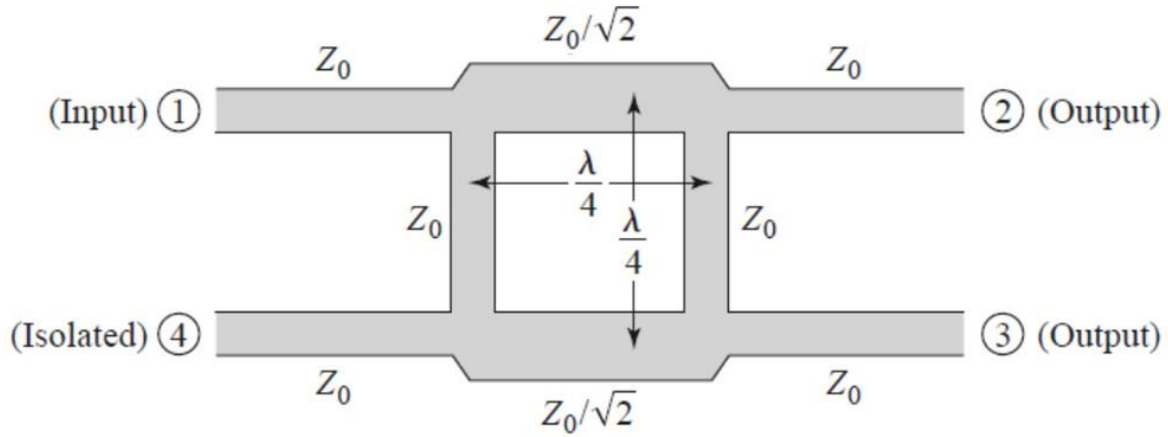


Fig. 1. Branch-line coupler. Here $Z_0 = 50\ \Omega$.

$$S = \begin{bmatrix} 0 & -\frac{j}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \\ -\frac{j}{\sqrt{2}} & 0 & 0 & -\frac{1}{\sqrt{2}} \\ -\frac{1}{\sqrt{2}} & 0 & 0 & -\frac{j}{\sqrt{2}} \\ 0 & -\frac{1}{\sqrt{2}} & -\frac{j}{\sqrt{2}} & 0 \end{bmatrix}$$

定向耦合器中的两个重要的指标：

耦合度C：输入端输入功率与耦合端的输出功率之比：

$$\mathrm{C} = 10\lg\frac{P_1}{P_3} = 10\lg\frac{1}{|S_{31}|^2}$$

耦合度C表征了耦合强弱。

隔离度I：输入端输入功率与隔离端的输出功率之比：

$$\mathrm{I} = 10\lg\frac{P_1}{P_4} = 10\lg\frac{1}{|S_{41}|^2}$$

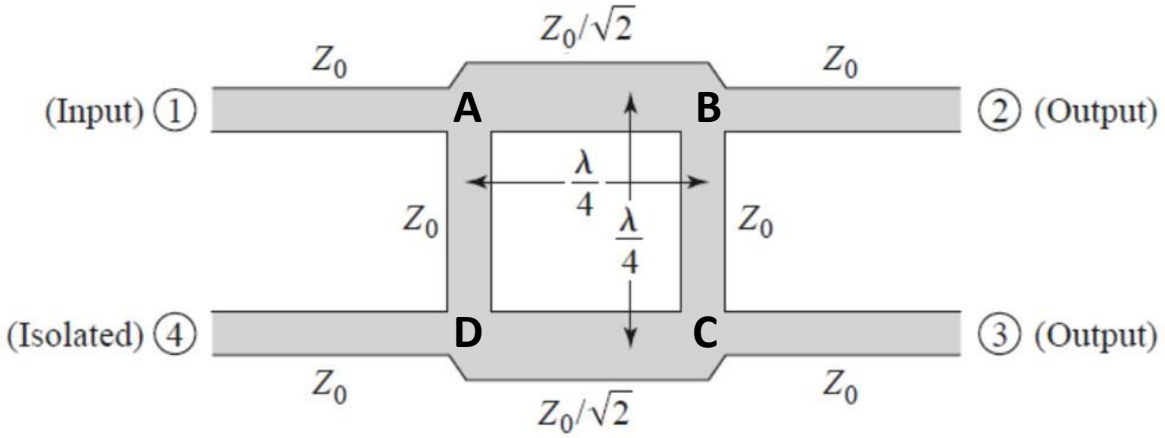


Fig. 1. Branch-line coupler. Here $Z_0 = 50\ \Omega$.

理想3dB分支线耦合器：

C = 3dB

I = ∞

设计一个3dB分支线定向耦合器

1. 基板Rogers 5870，厚度0.787mm
2. 中心频率：2GHz
3. 端口阻抗：50Ω
4. 带宽：100MHz
5. S11，S22，S33，S44<-15dB
6. S41<-20dB
7. S21，S31>-3.3dB
8. 中心频点abs(S31-S21)<0.1dB
9. 中心频点89°<|phase(S31)-phase(S21)|<91°

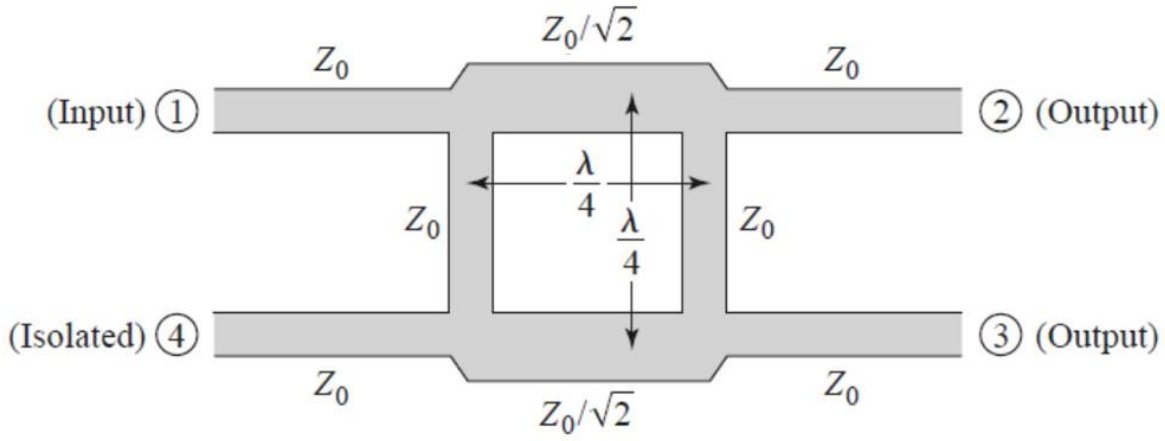
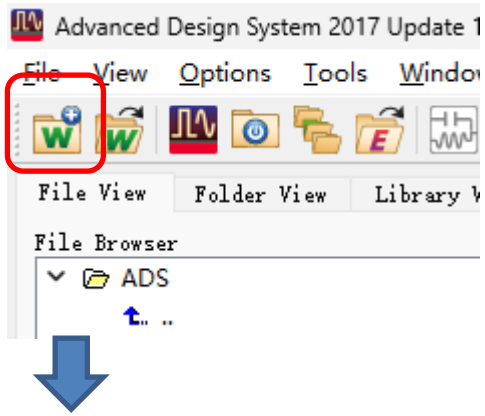
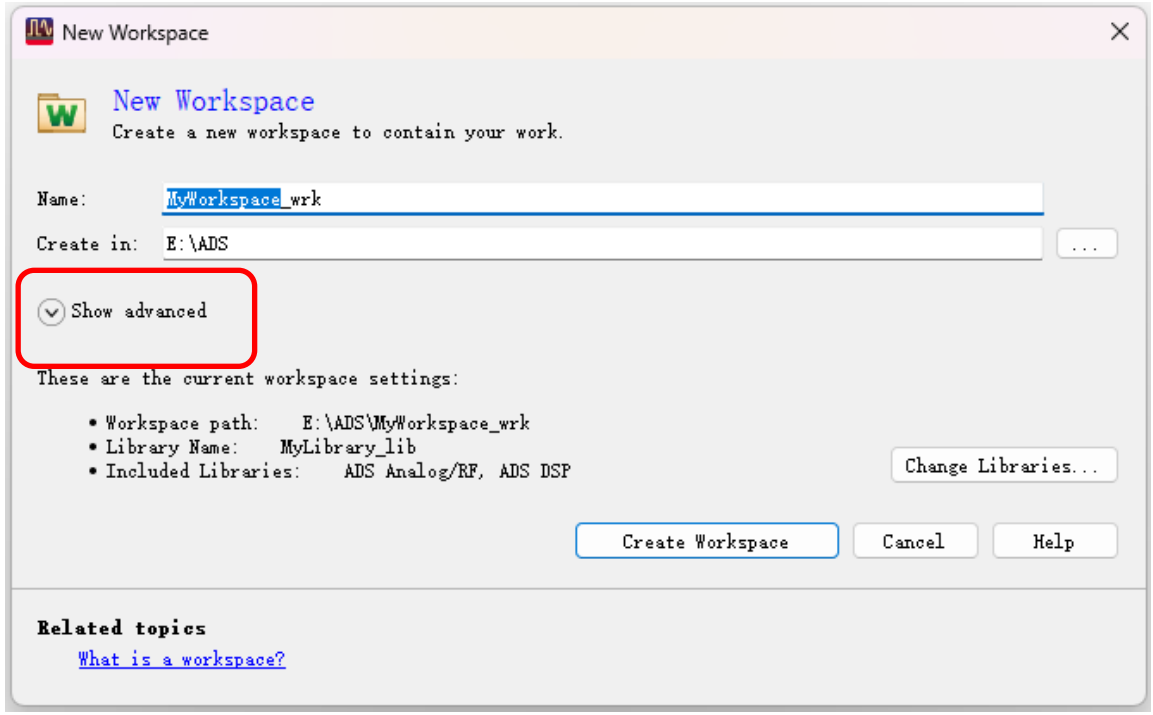
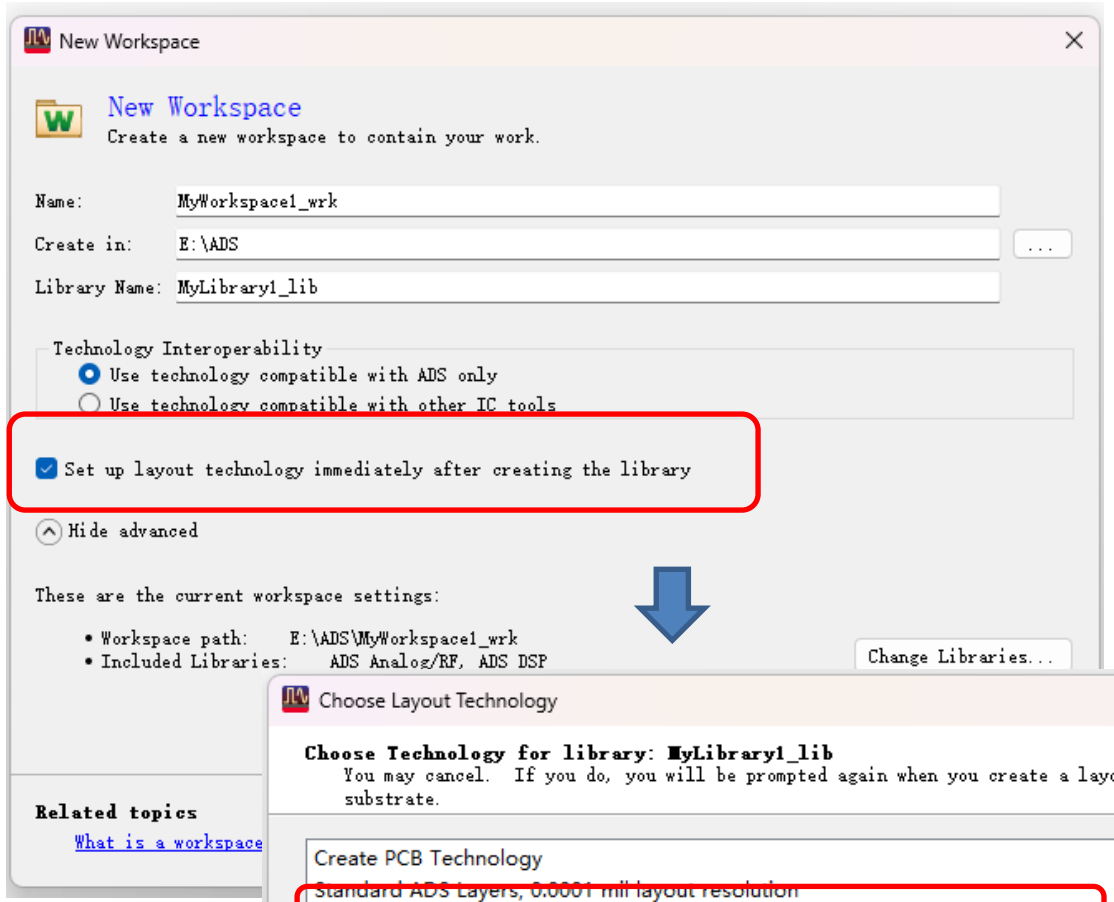
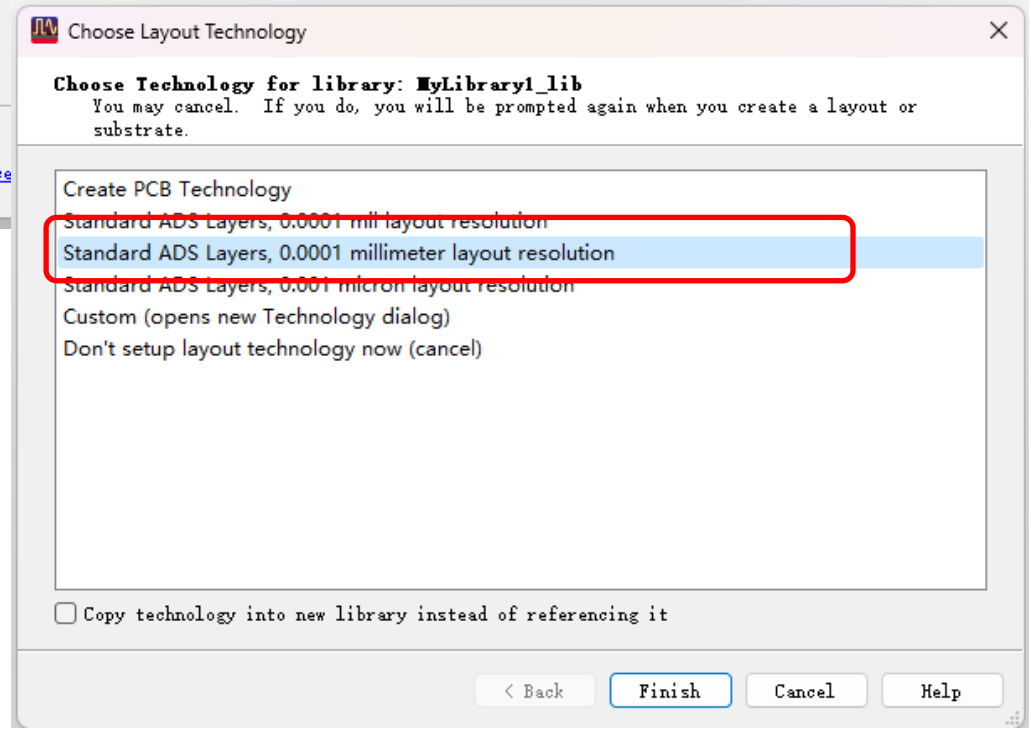


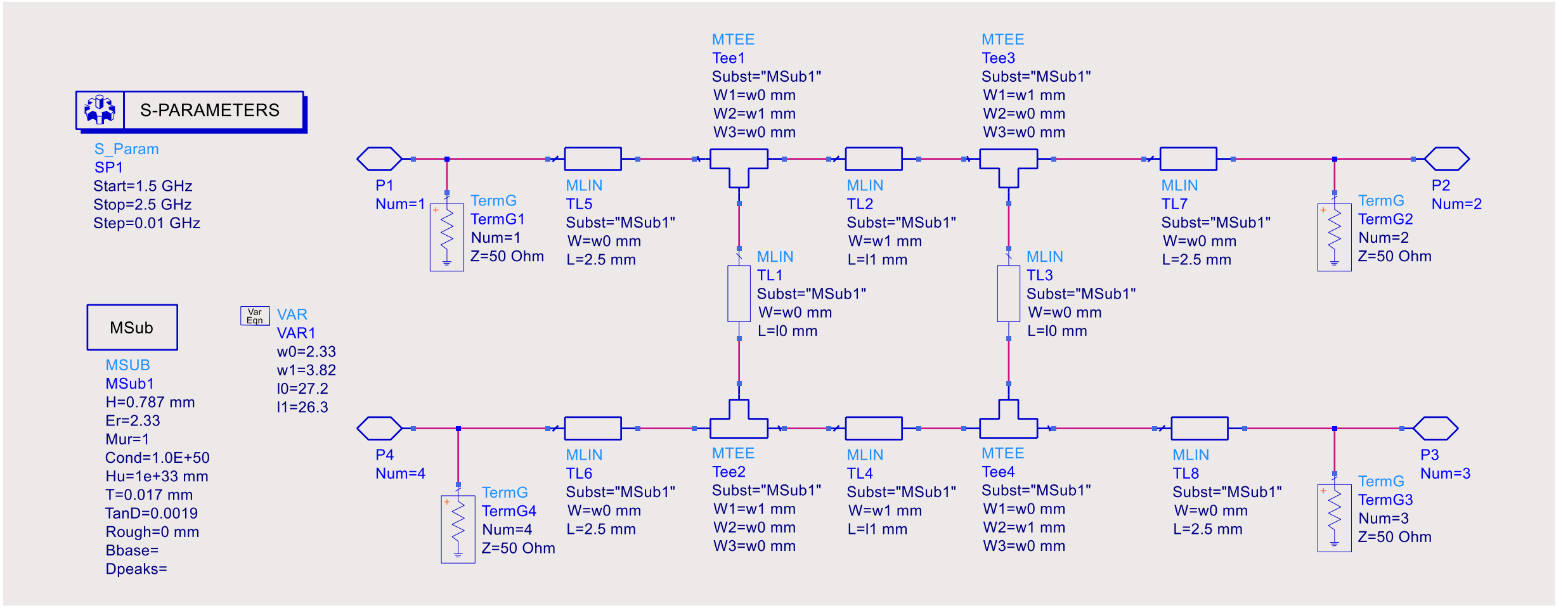
Fig. 1. Branch-line coupler. Here $Z_0 = 50\ \Omega$.

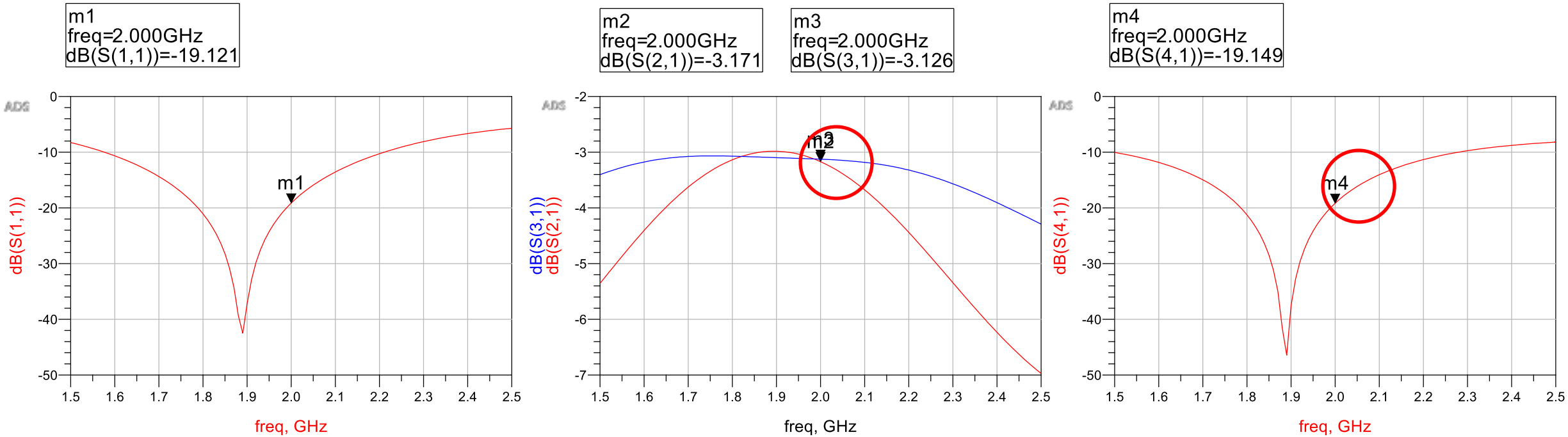

Advanced Design System 2017 Update 1
File View Options Tools Windo
File View
Folder View
Library
File Browser
ADS
..


New Workspace
New Workspace
Create a new workspace to contain your work.
Name: MyWorkspace_wrk
Create in: E:\ADS
...
Show advanced
These are the current workspace settings:
• Workspace path: E:\ADS\MyWorkspace_wrk
• Library Name: MyLibrary_lib
• Included Libraries: ADS Analog/RF, ADS DSP
Change Libraries...
Create Workspace
Cancel
Help
Related topics
What is a workspace?


New Workspace
New Workspace
Create a new workspace to contain your work.
Name: MyWorkspace1_wrk
Create in: E:\ADS
...
Library Name: MyLibrary1_lib
Technology Interoperability
Use technology compatible with ADS only
Use technology compatible with other IC tools
Set up layout technology immediately after creating the library
Hide advanced
These are the current workspace settings:
• Workspace path: E:\ADS\MyWorkspace1_wrk
• Included Libraries: ADS Analog/RF, ADS DSP
Change Libraries...
Related topics
What is a workspace


Choose Layout Technology
Choose Technology for library: MyLibrary1_lib
You may cancel. If you do, you will be prompted again when you create a layout or substrate.
Create PCB Technology
Standard ADS Layers, 0.0001 mil layout resolution
Standard ADS Layers, 0.0001 millimeter layout resolution
Standard ADS Layers, 0.001 micron layout resolution
Custom (opens new Technology dialog)
Don't setup layout technology now (cancel)
Copy technology into new library instead of referencing it
< Back
Finish
Cancel
Help


S-PARAMETERS
S_Param
SP1
Start=1.5 GHz
Stop=2.5 GHz
Step=0.01 GHz
MSub
MSUB
MSub1
H=0.787 mm
Er=2.33
Mur=1
Cond=1.0E+50
Hu=1e+33 mm
T=0.017 mm
TanD=0.0019
Rough=0 mm
Bbase=
Dpeaks=
Var Eqn
VAR
VAR1
w0=2.33
w1=3.82
l0=27.2
l1=26.3
P1
Num=1
TermG
TermG1
Num=1
Z=50 Ohm
MLIN
TL5
Subst="MSub1"
W=w0 mm
L=2.5 mm
MTEE
Tee1
Subst="MSub1"
W1=w0 mm
W2=w1 mm
W3=w0 mm
MLIN
TL1
Subst="MSub1"
W=w0 mm
L=l0 mm
MLIN
TL2
Subst="MSub1"
W=w1 mm
L=l1 mm
MTEE
Tee3
Subst="MSub1"
W1=w1 mm
W2=w0 mm
W3=w0 mm
MLIN
TL3
Subst="MSub1"
W=w0 mm
L=l0 mm
MLIN
TL7
Subst="MSub1"
W=w0 mm
L=2.5 mm
TermG
TermG2
Num=2
Z=50 Ohm
P2
Num=2
P4
Num=4
TermG
TermG4
Num=4
Z=50 Ohm
MLIN
TL6
Subst="MSub1"
W=w0 mm
L=2.5 mm
MTEE
Tee2
Subst="MSub1"
W1=w1 mm
W2=w0 mm
W3=w0 mm
MLIN
TL4
Subst="MSub1"
W=w1 mm
L=l1 mm
MTEE
Tee4
Subst="MSub1"
W1=w0 mm
W2=w1 mm
W3=w0 mm
MLIN
TL8
Subst="MSub1"
W=w0 mm
L=2.5 mm
TermG
TermG3
Num=3
Z=50 Ohm
P3
Num=3


m1
freq=2.000GHz
dB(S(1,1))=-19.121
m2
freq=2.000GHz
dB(S(2,1))=-3.171
m3
freq=2.000GHz
dB(S(3,1))=-3.126
m4
freq=2.000GHz
dB(S(4,1))=-19.149
dB(S(1,1))
dB(S(3,1))
dB(S(2,1))
dB(S(4,1))
freq, GHz
freq, GHz
freq, GHz

GOAL

Goal
OptimGoal1
Expr="dB(S11)"
SimInstanceName="SP1"
Weight=1

GOAL

Goal
OptimGoal2
Expr="dB(S21)"
SimInstanceName="SP1"
Weight=1

GOAL

Goal
OptimGoal3
Expr="dB(S31)"
SimInstanceName="SP1"
Weight=1

GOAL

Goal
OptimGoal4
Expr="dB(S41)"
SimInstanceName="SP1"
Weight=1

GOAL

Goal
OptimGoal5
Expr="abs(dB(S31)-dB(S21))"
SimInstanceName="SP1"
Weight=1

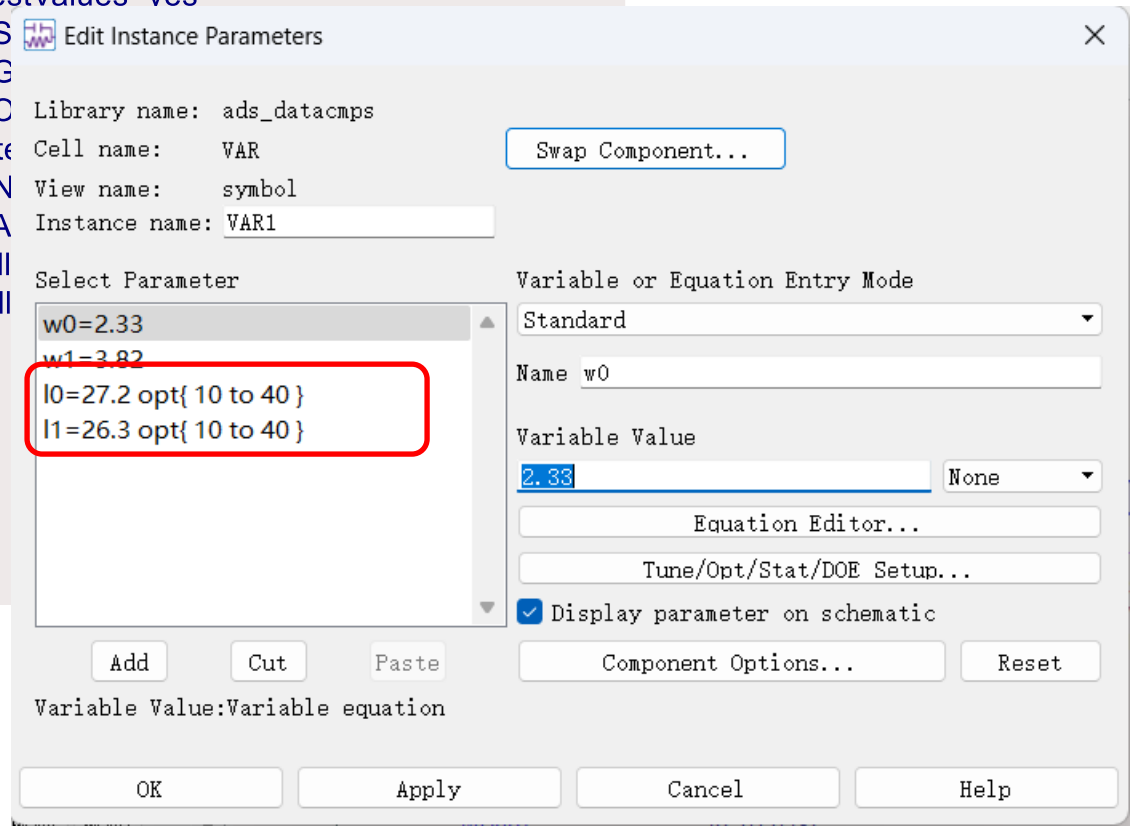
GOAL

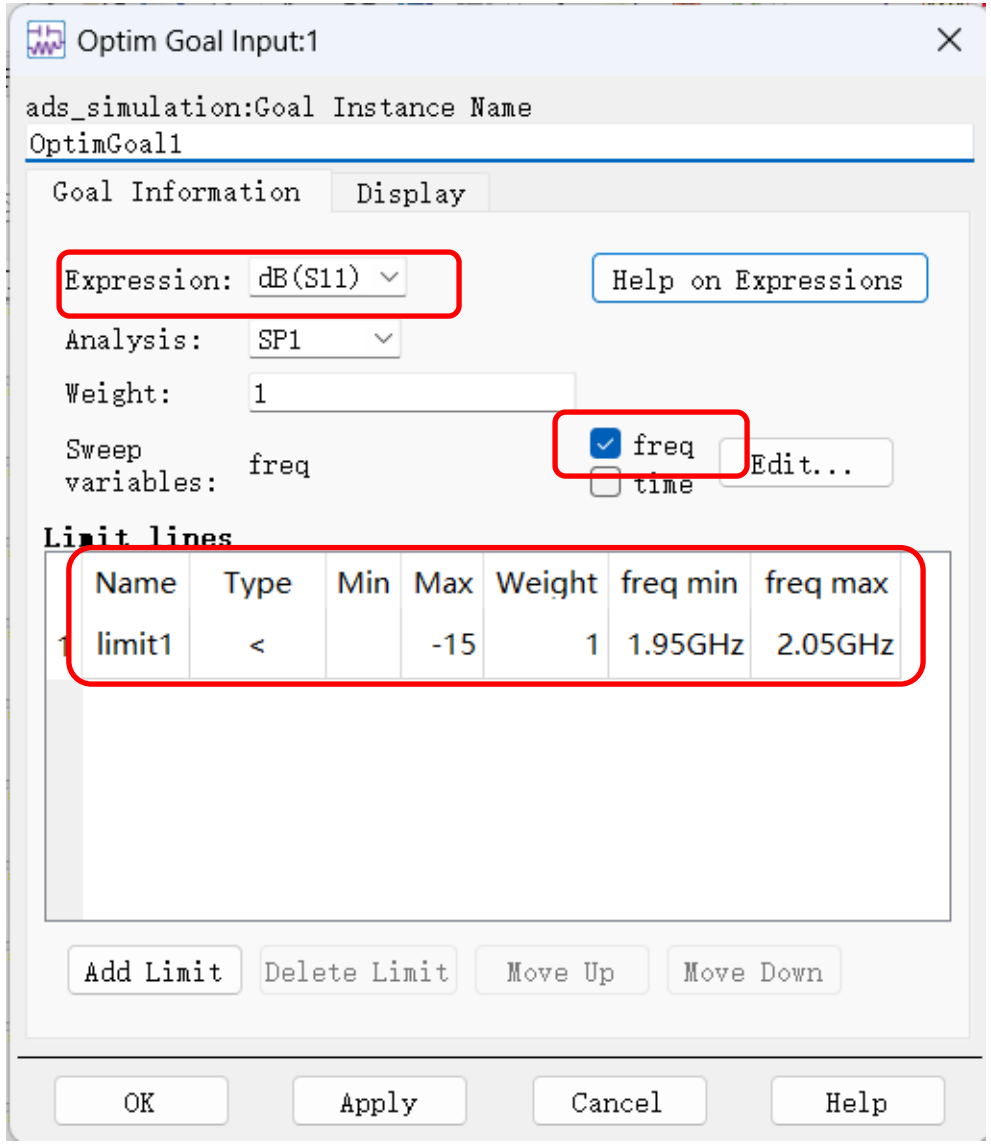
Goal
OptimGoal6
Expr="phase(S31)-phase(S21)-180"
SimInstanceName="SP1"
Weight=1

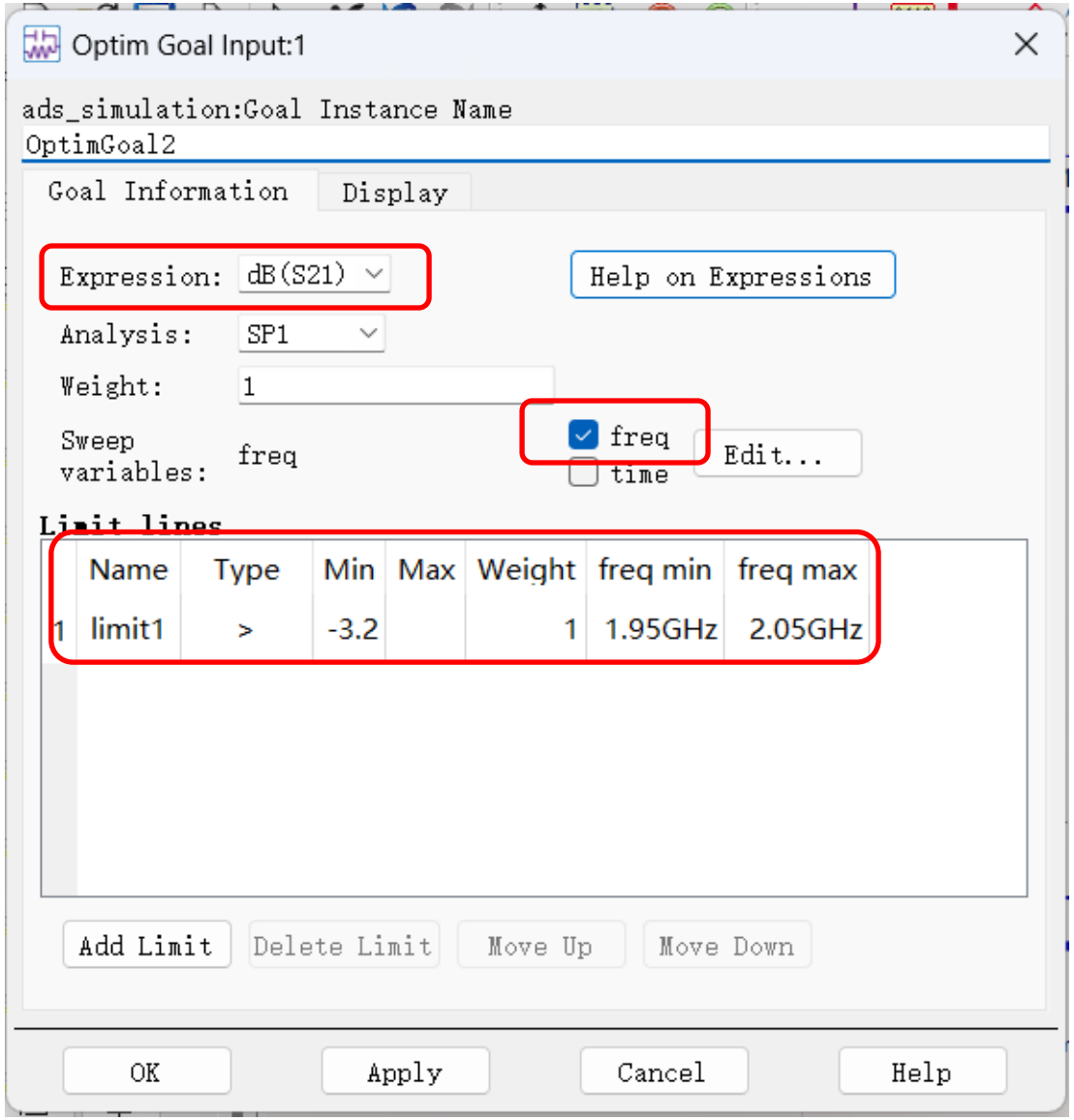
next 3 pages

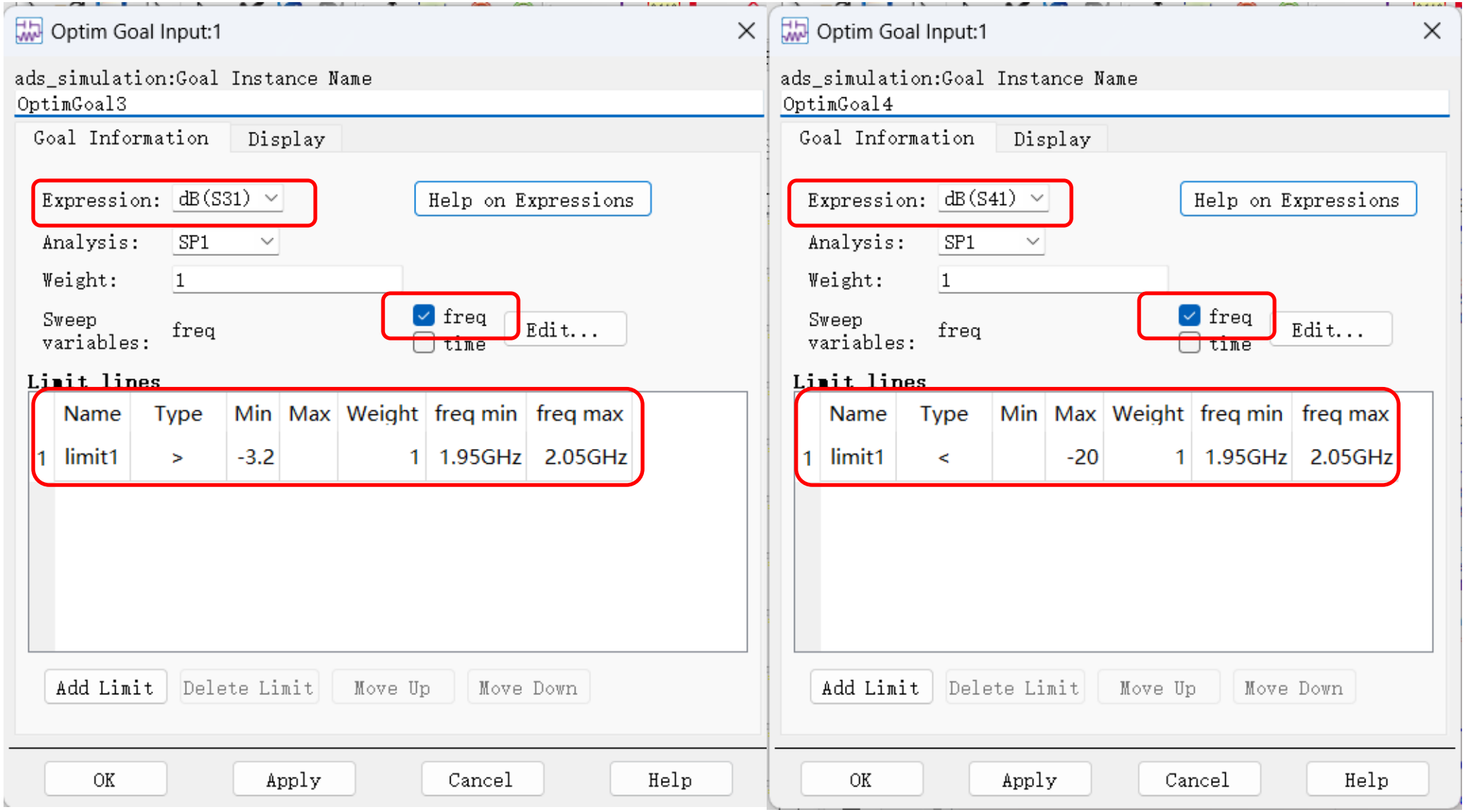
OPTIM

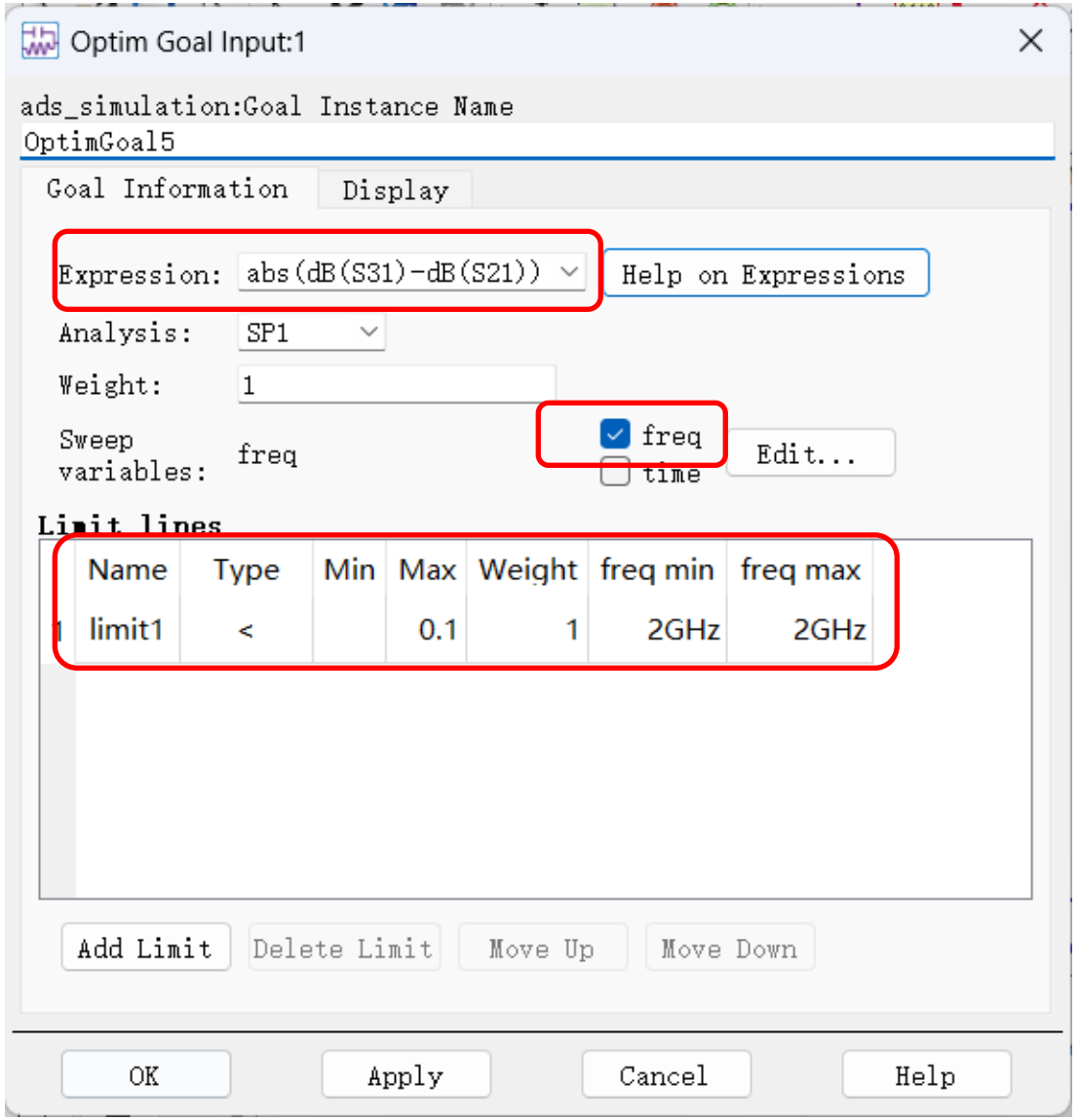
Optim
Optim1
OptimType=Random
MaxIters=100
DesiredError=0.0
StatusLevel=4
FinalAnalysis="None"
NormalizeGoals=yes
SetBestValues=ves
SaveS
SaveG
SaveC
Update
SaveN
SaveA
UseAll
UseAll
SaveCurrentEF=no
EnableCockpit=yes
SaveAllTrials=no

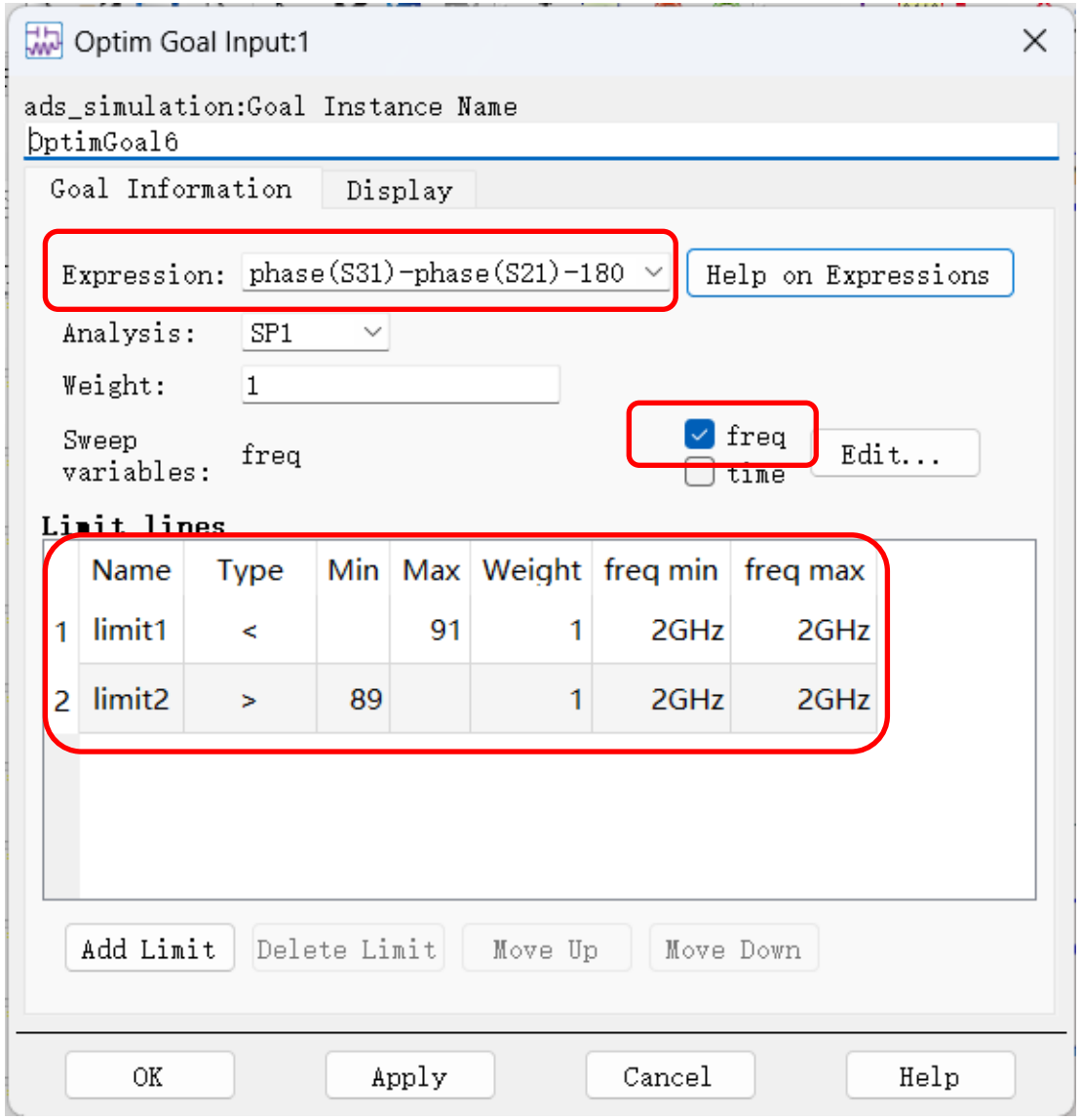


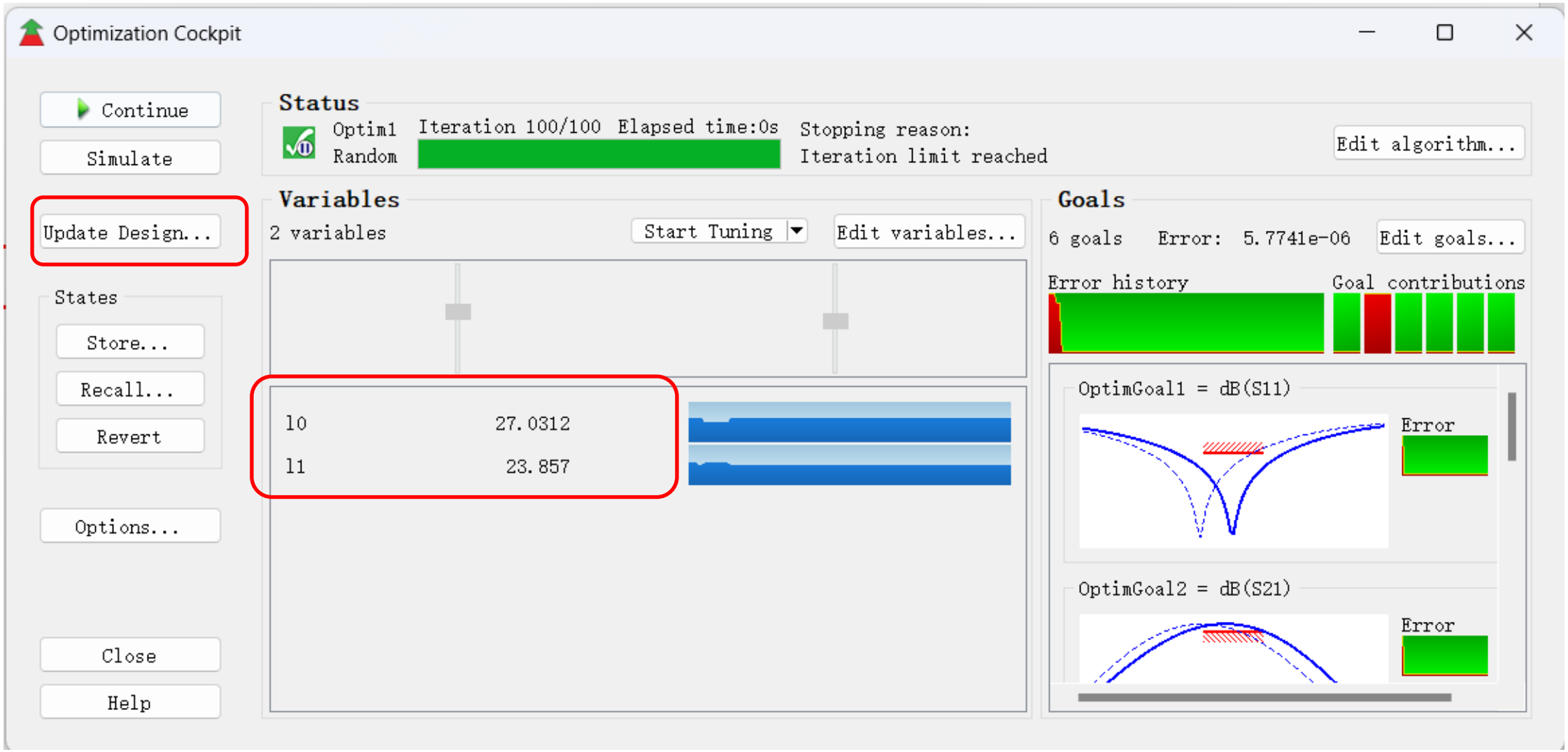

Optim Goal Input:1
ads_simulation:Goal Instance Name
OptimGoal1
Goal Information
Display
Expression: dB(S11)
Help on Expressions
Analysis: SP1
Weight: 1
Sweep variables: freq
freq
time
Edit...
Limit lines
Name Type Min Max Weight freq min freq max
1 limit1 < -15 1 1.95GHz 2.05GHz
Add Limit
Delete Limit
Move Up
Move Down
OK
Apply
Cancel
Help

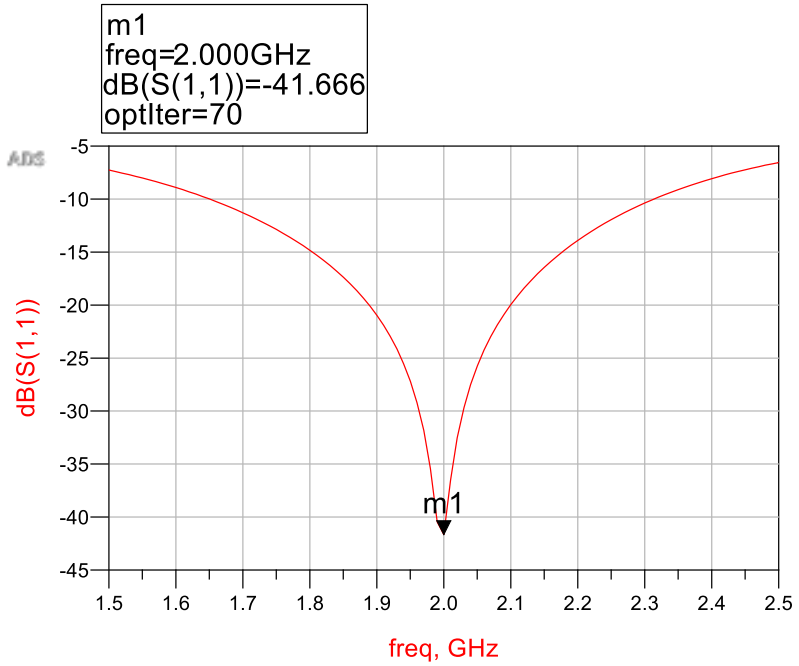

Optim Goal Input:1
ads_simulation:Goal Instance Name
OptimGoal2
Goal Information
Display
Expression: dB(S21)
Help on Expressions
Analysis: SP1
Weight: 1
Sweep variables: freq
freq
time
Edit...
Limit lines
Name Type Min Max Weight freq min freq max
1 limit1 > -3.2 1 1.95GHz 2.05GHz
Add Limit
Delete Limit
Move Up
Move Down
OK
Apply
Cancel
Help

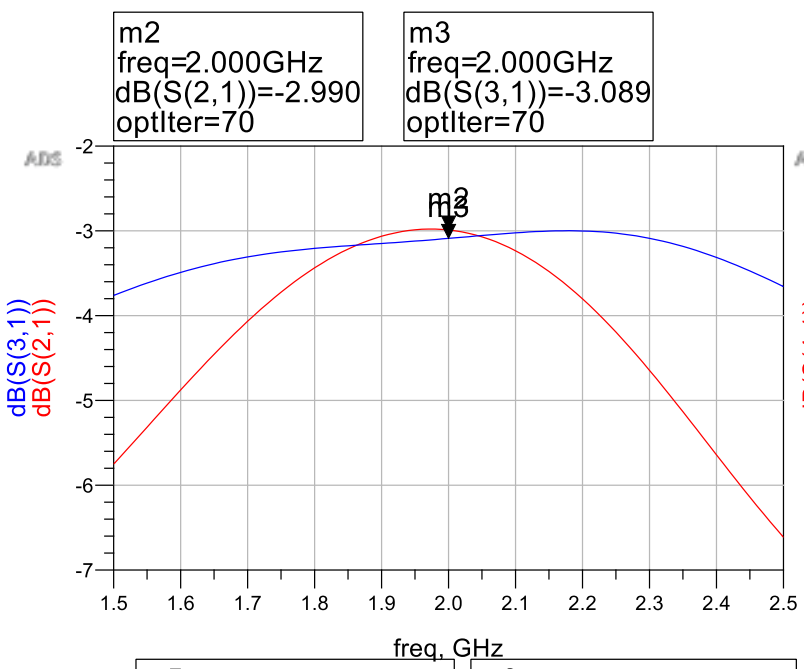

Optim Goal Input:1
ads_simulation:Goal Instance Name
OptimGoal3
Goal Information
Display
Expression: dB(S31)
Help on Expressions
Analysis: SP1
Weight: 1
Sweep variables: freq
freq
time
Edit...
Limit lines
Name Type Min Max Weight freq min freq max
1 limit1 > -3.2 1 1.95GHz 2.05GHz
Add Limit
Delete Limit
Move Up
Move Down
OK
Apply
Cancel
Help
Optim Goal Input:1
ads_simulation:Goal Instance Name
OptimGoal4
Goal Information
Display
Expression: dB(S41)
Help on Expressions
Analysis: SP1
Weight: 1
Sweep variables: freq
freq
time
Edit...
Limit lines
Name Type Min Max Weight freq min freq max
1 limit1 < -20 1 1.95GHz 2.05GHz
Add Limit
Delete Limit
Move Up
Move Down
OK
Apply
Cancel
Help

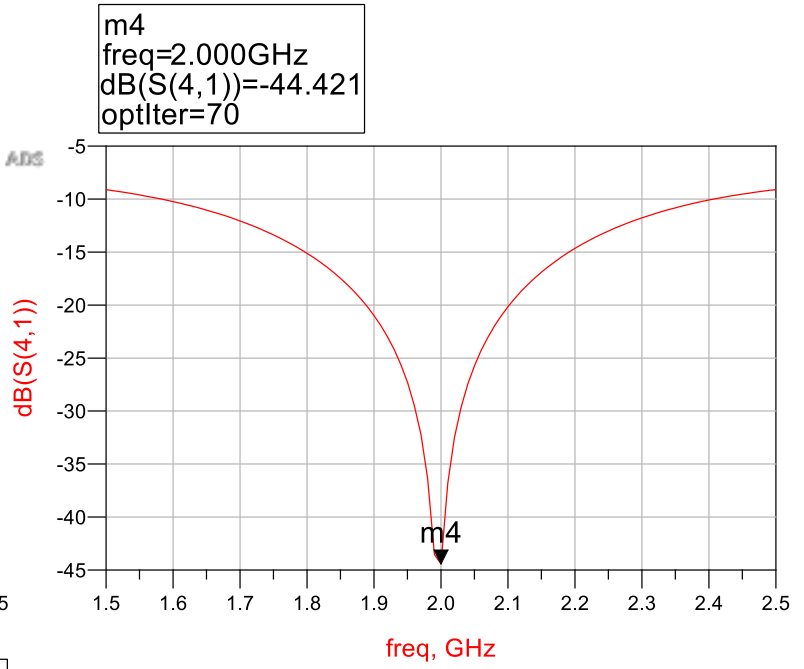

Optim Goal Input:1
ads_simulation:Goal Instance Name
OptimGoal5
Goal Information
Display
Expression: abs(dB(S31)-dB(S21))
Help on Expressions
Analysis: SP1
Weight: 1
Sweep variables: freq
freq
time
Edit...
Limit lines
Name Type Min Max Weight freq min freq max
1 limit1 < 0.1 1 2GHz 2GHz
Add Limit
Delete Limit
Move Up
Move Down
OK
Apply
Cancel
Help

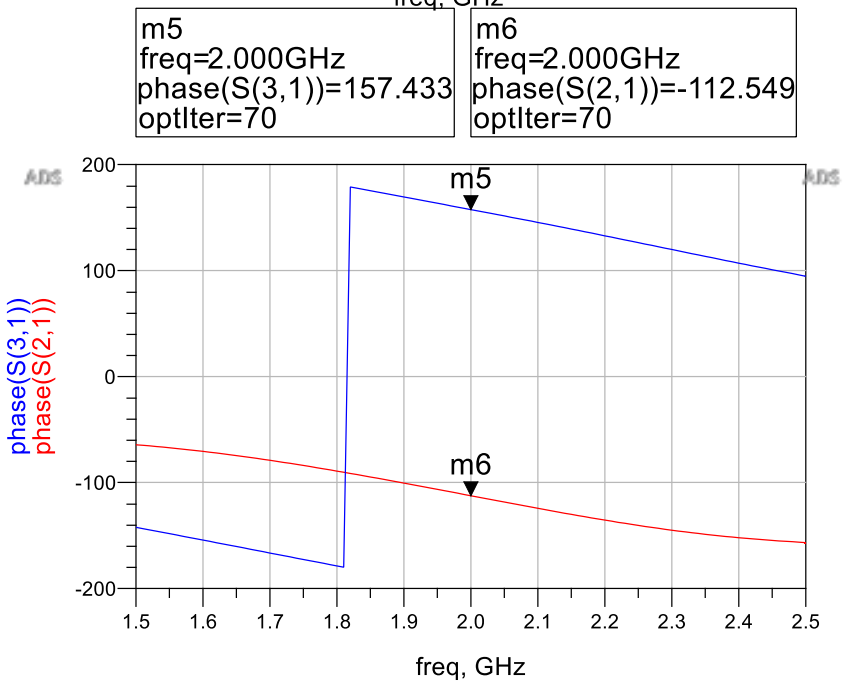

Optim Goal Input:1
ads_simulation:Goal Instance Name
OptimGoal6
Goal Information
Display
Expression: phase(S31)-phase(S21)-180
Help on Expressions
Analysis: SP1
Weight: 1
Sweep variables: freq
freq
time
Edit...
Limit lines
Name Type Min Max Weight freq min freq max
1 limit1 < 91 1 2GHz 2GHz
2 limit2 > 89 1 2GHz 2GHz
Add Limit
Delete Limit
Move Up
Move Down
OK
Apply
Cancel
Help

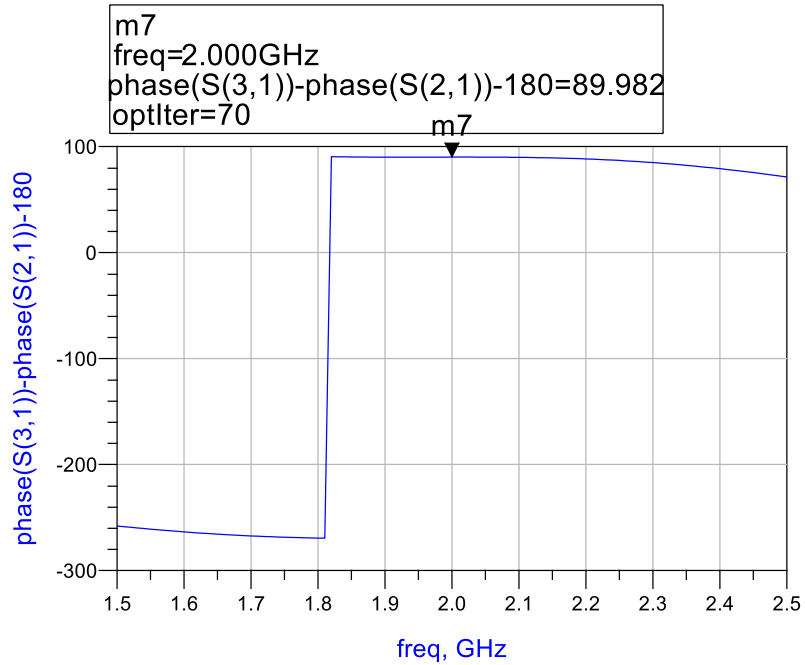

Optimization Cockpit
Continue
Simulate
Update Design...
States
Store...
Recall...
Revert
Options...
Close
Help
Status
Optim1
Random
Iteration 100/100 Elapsed time:0s
Stopping reason:
Iteration limit reached
Edit algorithm...
Variables
2 variables
Start Tuning
Edit variables...
l0 27.0312
l1 23.857
Goals
6 goals Error: 5.7741e-06
Edit goals...
Error history
Goal contributions
OptimGoal1 = dB(S11)
Error
OptimGoal2 = dB(S21)
Error

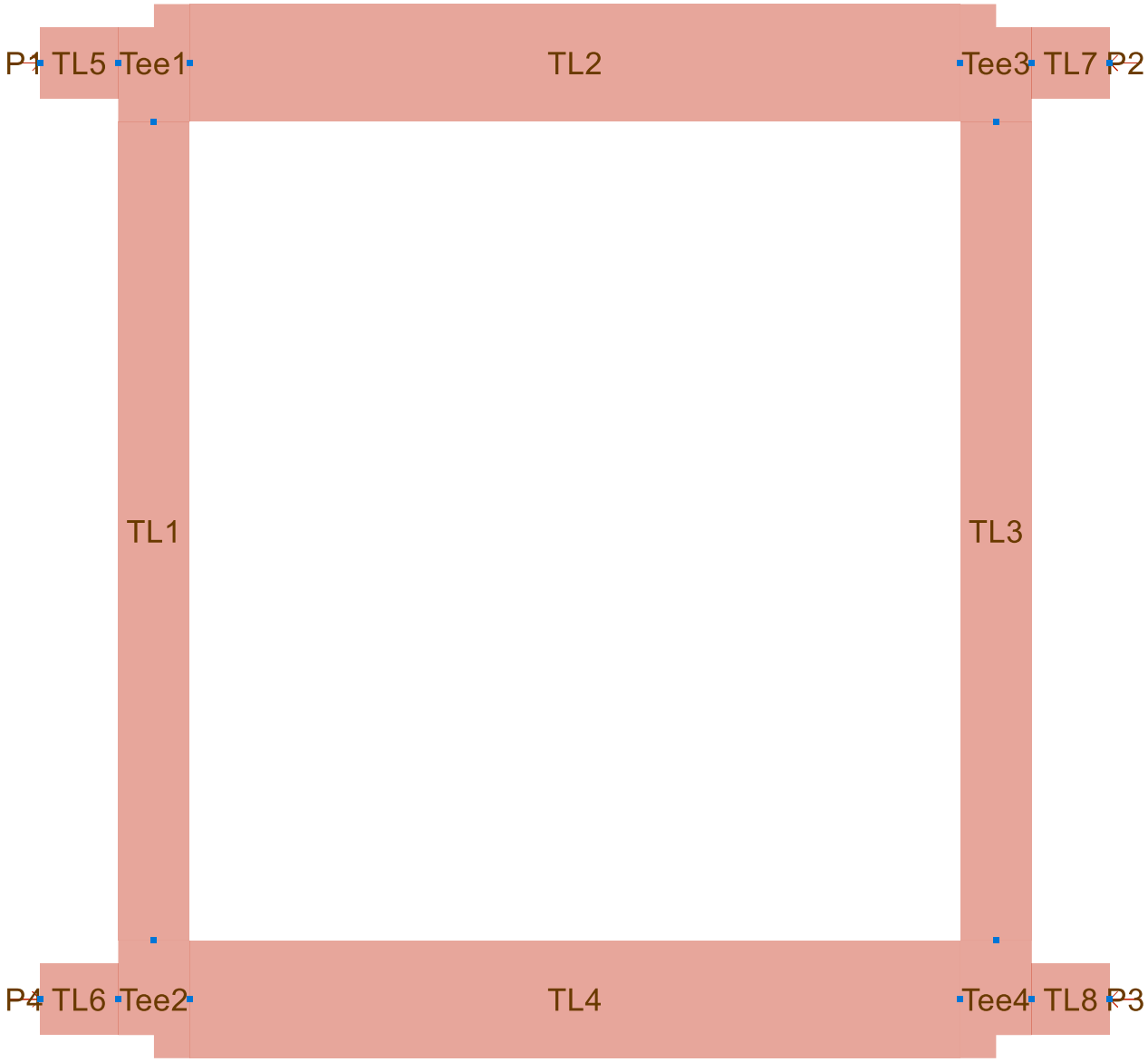

m1
freq=2.000GHz
dB(S(1,1))=-41.666
optIter=70
dB(S(1,1))
freq, GHz


m2
freq=2.000GHz
dB(S(2,1))=-2.990
optIter=70
m3
freq=2.000GHz
dB(S(3,1))=-3.089
optIter=70
dB(S(3,1))
dB(S(2,1))
freq, GHz


m4
freq=2.000GHz
dB(S(4,1))=-44.421
optIter=70
dB(S(4,1))
freq, GHz


m5
freq=2.000GHz
phase(S(3,1))=157.433
optIter=70
m6
freq=2.000GHz
phase(S(2,1))=-112.549
optIter=70
phase(S(3,1))
phase(S(2,1))
freq, GHz

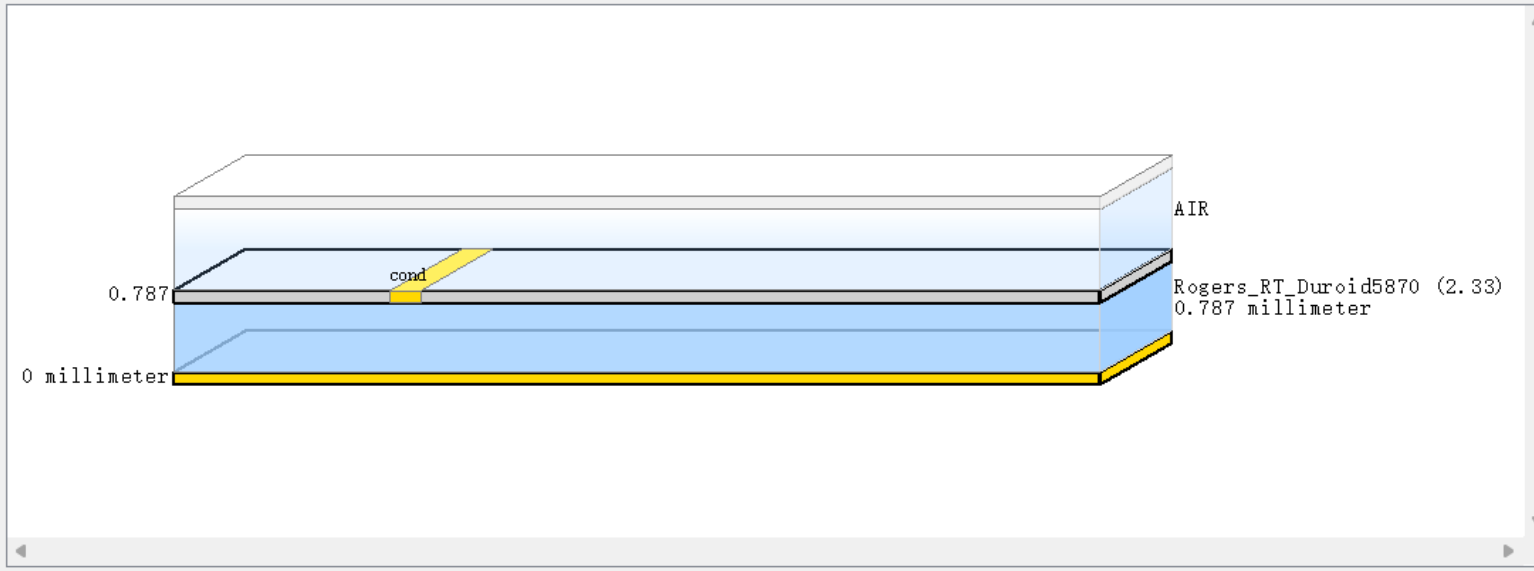

m7
freq=2.000GHz
phase(S(3,1))-phase(S(2,1))-180=89.982
optIter=70
phase(S(3,1))-phase(S(2,1))-180
freq, GHz


P1
TL5
Tee1
TL2
Tee3
TL7
P2
TL1
TL3
P4
TL6
Tee2
TL4
Tee4
TL8
P3

substrate1 [Coupler_lib] (Substrate):5

File Technology Edit View Options Tools Window Help

Substrate Name: substrate1



Use right mouse context menus to add or delete substrate items.

Select items on the substrate and view their properties below.

Shortcuts in the Edit menu can be used to quickly edit the next substrate item.

Entire Substrate

Bounding area layer: <none> ...

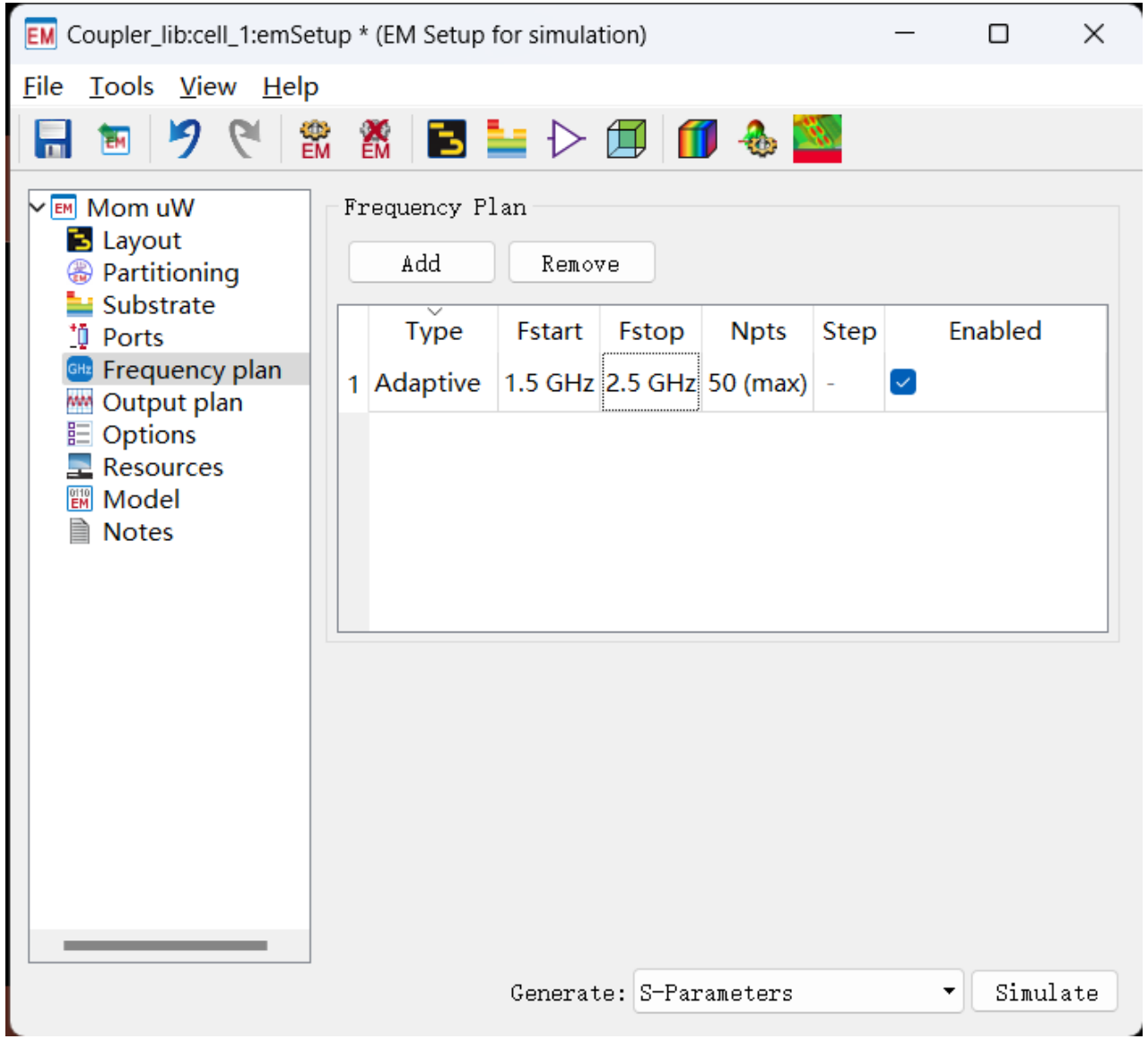
Substrate Layer Stackup

	Type	Name	Material	Thickness
	Dielectric		AIR	
1	Conductor L...	cond (1)	PERFECT_CONDUCTOR	0.017 mm
	Dielectric		Rogers_RT_Duroid5870	0.787 mm
	Cover		PERFECT_CONDUCTOR	0.017 mm

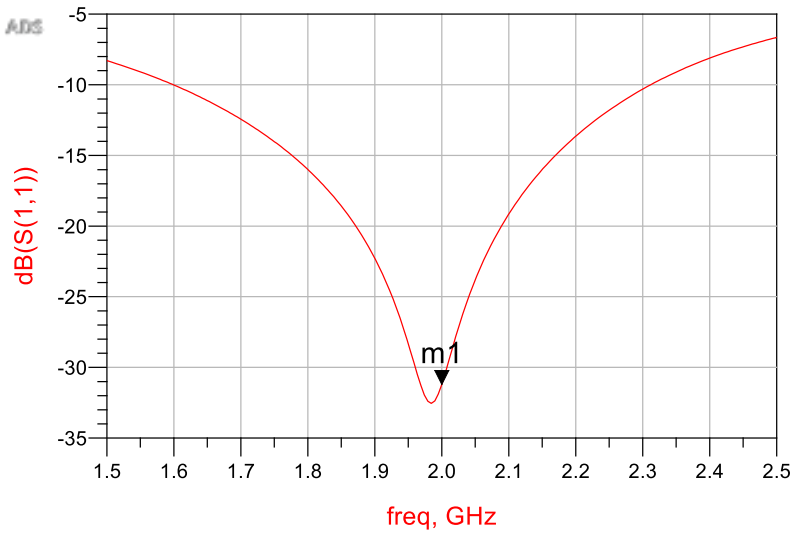
Substrate Vias

Type	Name	Top	Bottom	Mate

Select a substrate item to see more information about that item.

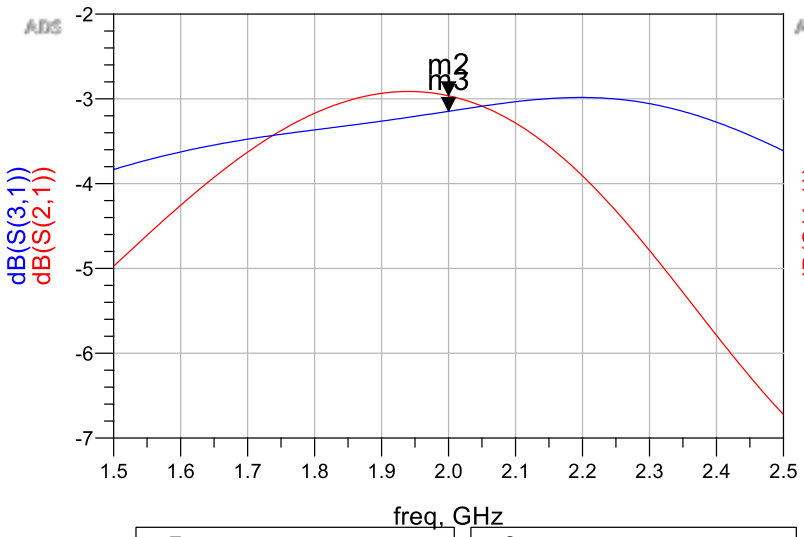

Coupler_lib:cell_1:emSetup * (EM Setup for simulation)
File
Tools
View
Help
Mom uW
Layout
Partitioning
Substrate
Ports
Frequency plan
Output plan
Options
Resources
Model
Notes
Frequency Plan
Add
Remove
Type
Fstart
Fstop
Npts
Step
Enabled
1
Adaptive
1.5 GHz
2.5 GHz
50 (max)
-
Generate:
S-Parameters
Simulate

m1
freq=2.000GHz
dB(S(1,1))=-31.207

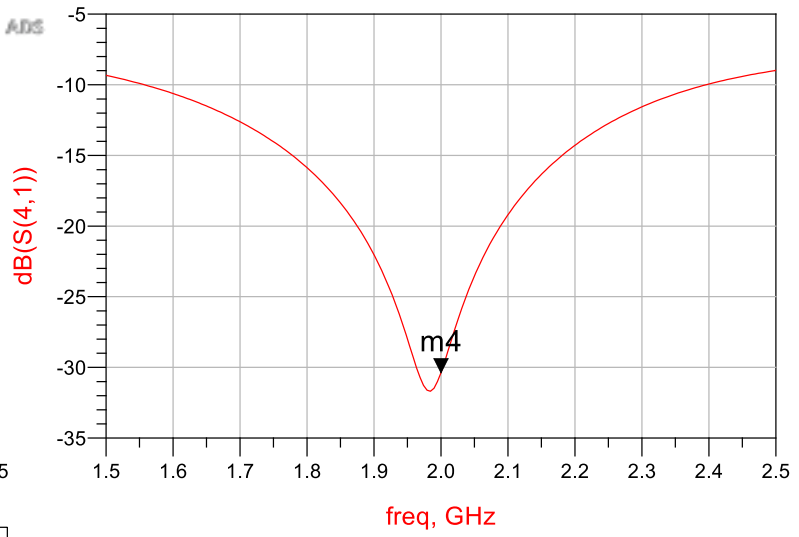


m2
freq=2.000GHz
dB(S(2,1))=-2.964

m3
freq=2.000GHz
dB(S(3,1))=-3.146

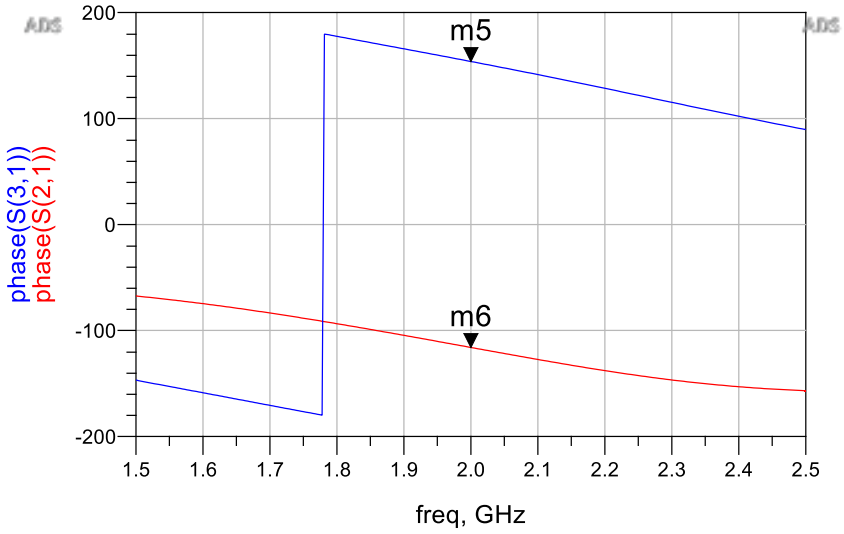


m4
freq=2.000GHz
dB(S(4,1))=-30.371

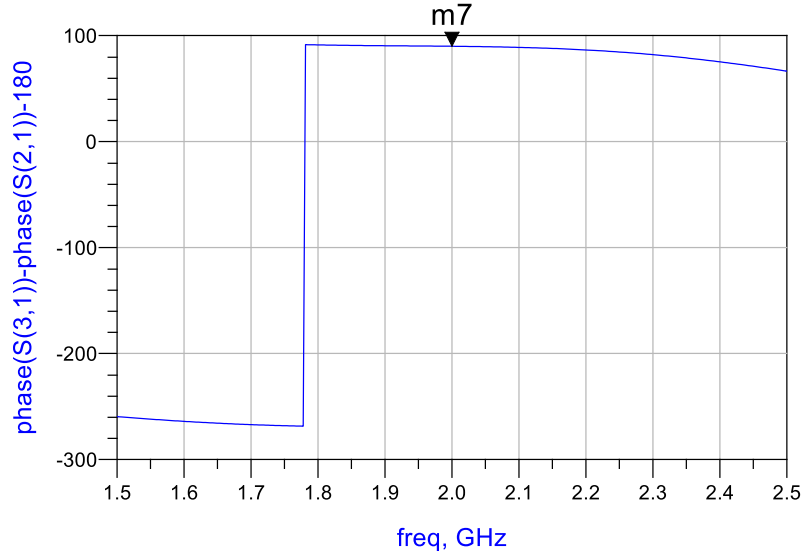


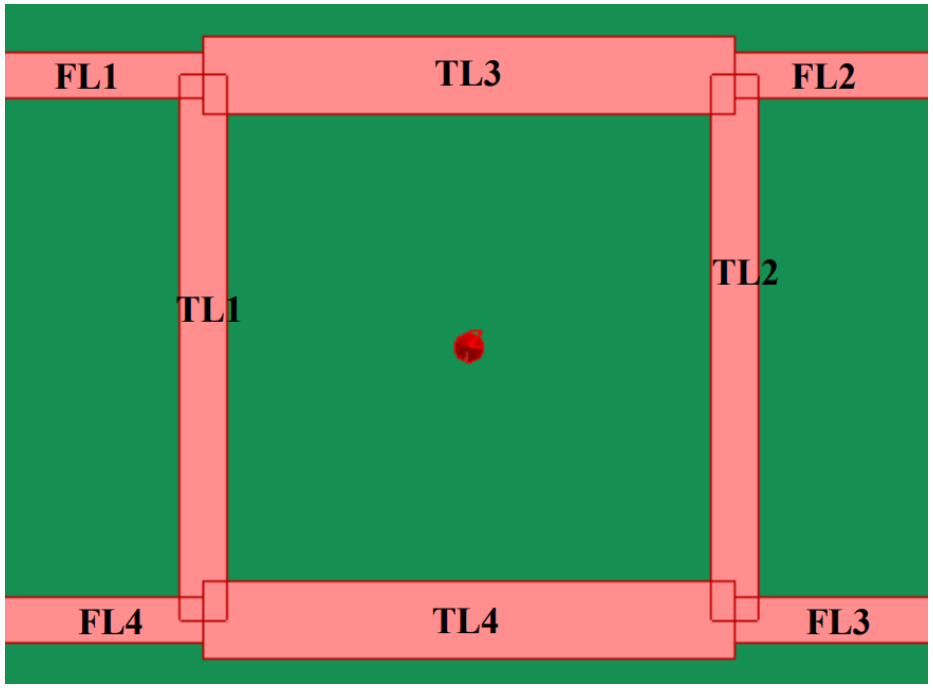
m5
freq=2.000GHz
phase(S(3,1))=153.763

m6
freq=2.000GHz
phase(S(2,1))=-116.052

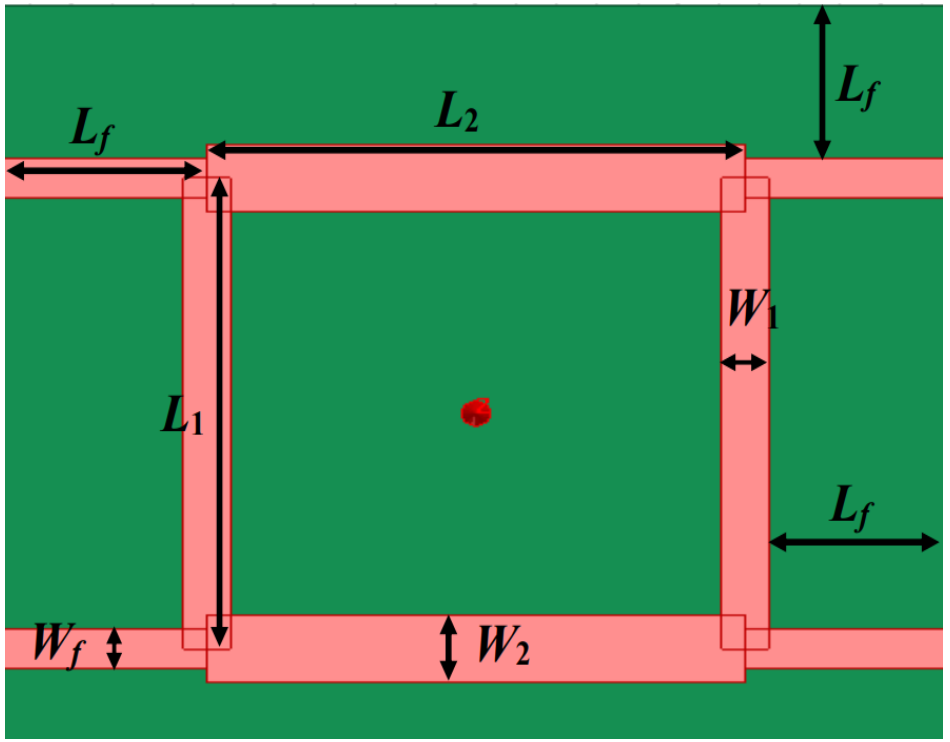


m7
freq=2.000GHz
phase(S(3,1))-phase(S(2,1))-180=89.814

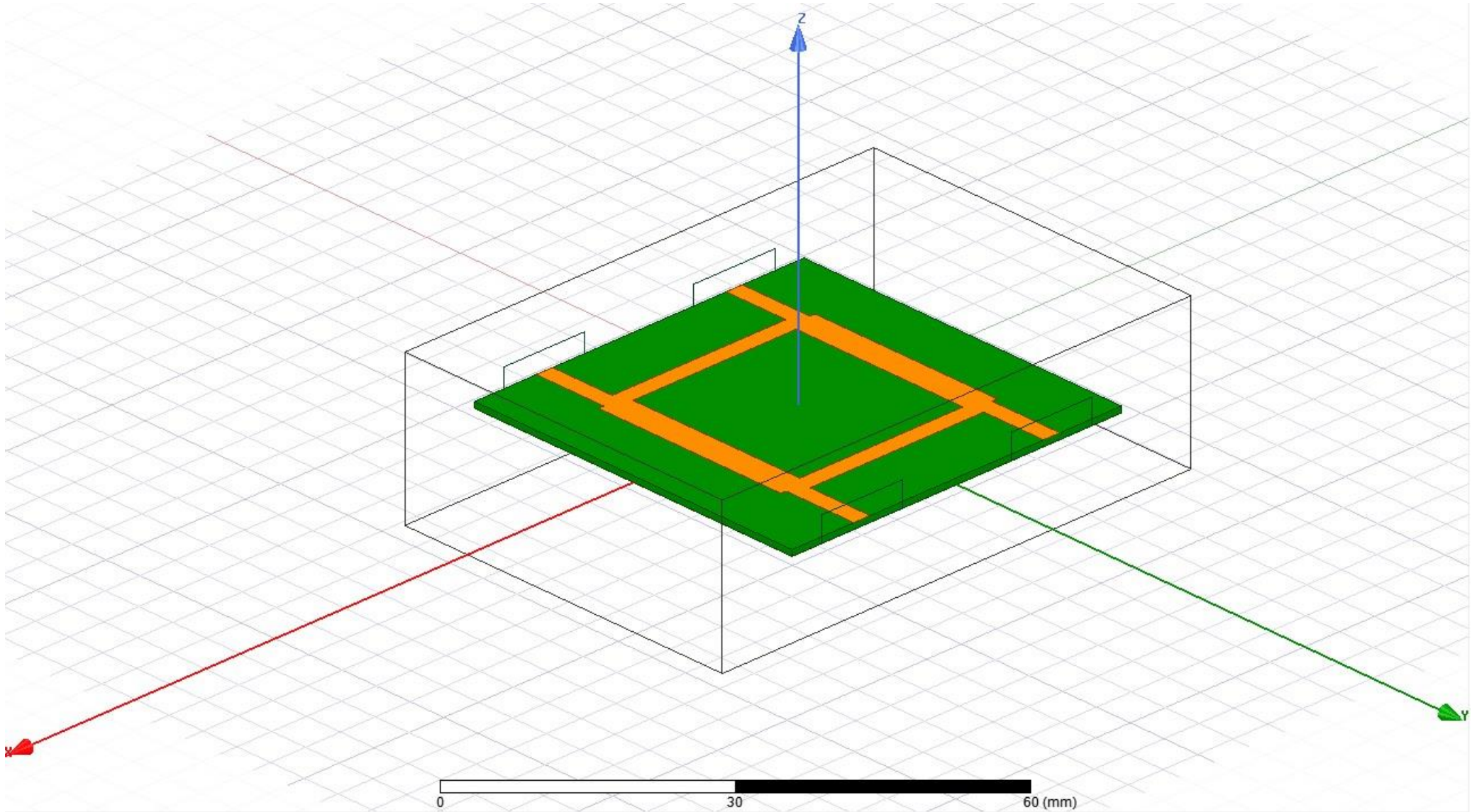


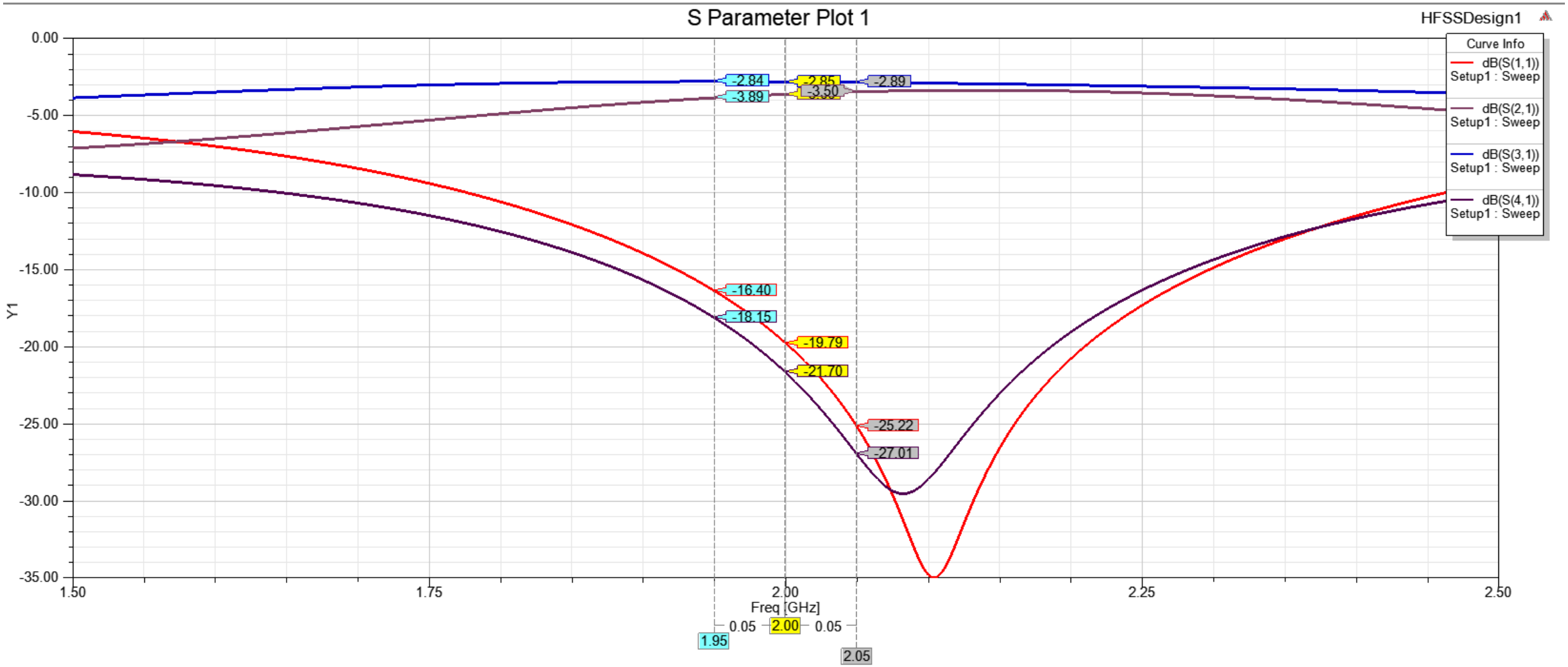


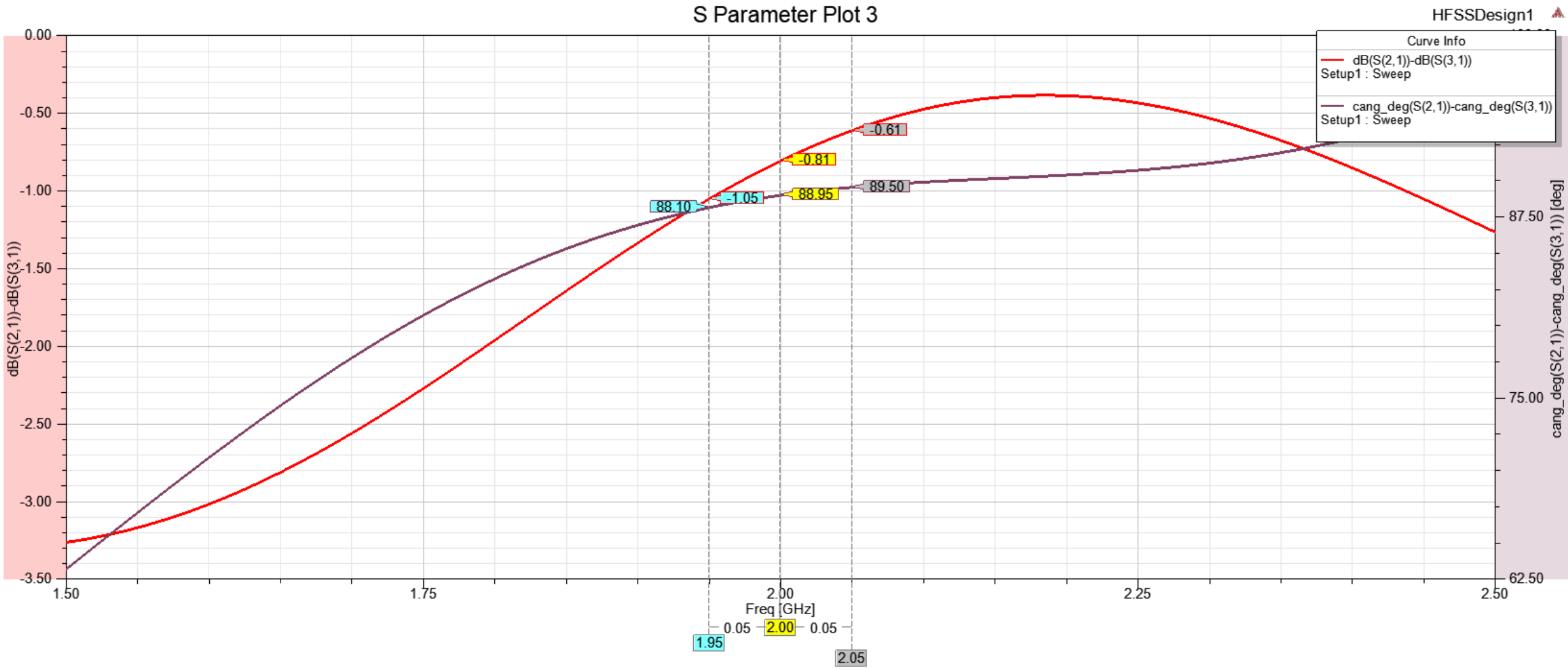
EXPT6.pdf

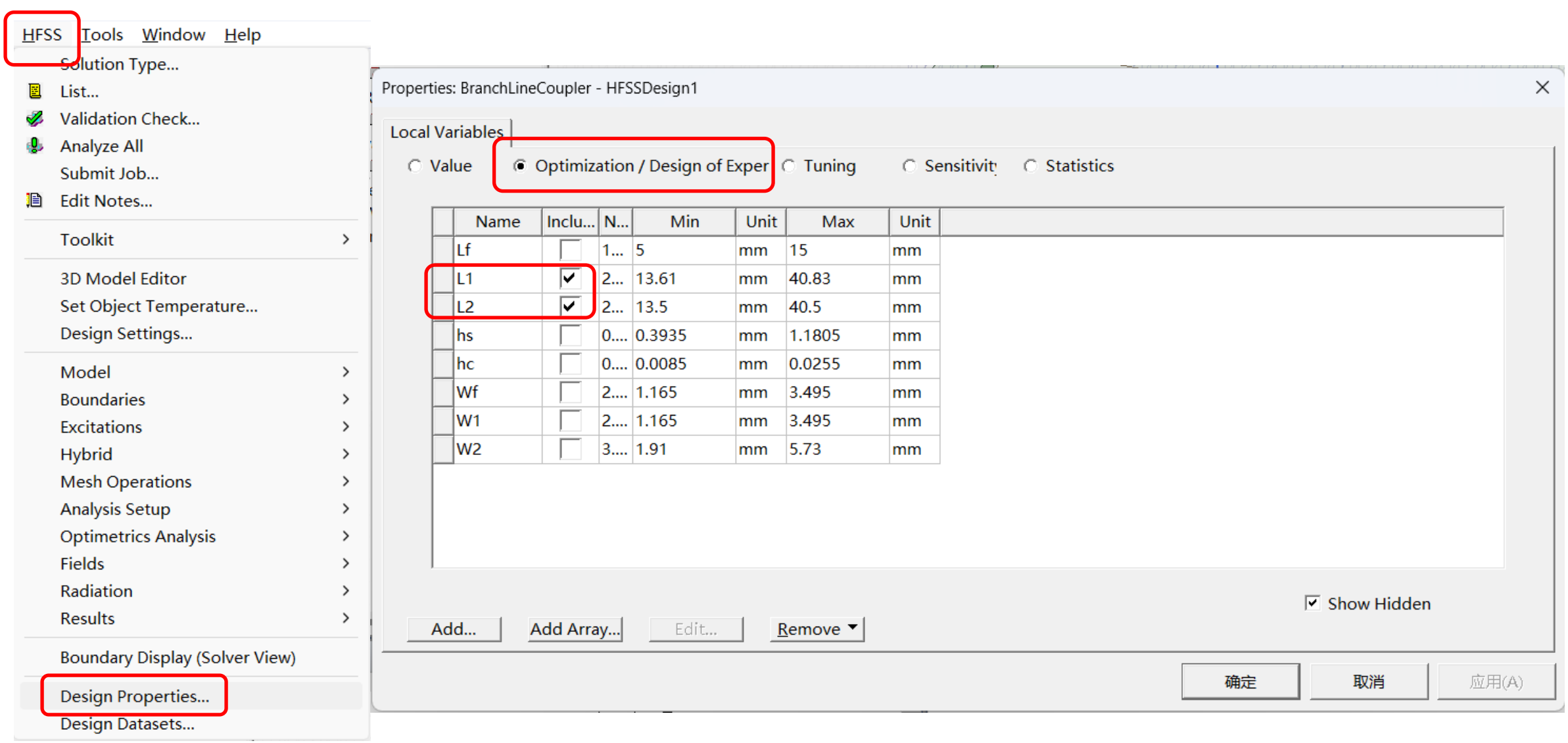


Name	Value	Unit	Evaluated...
hs	0.787	mm	0.787mm
hc	0.017	mm	0.017mm
Lf	10	mm	10mm
Wf	2.33	mm	2.33mm
L1	27.22	mm	27.22mm
W1	2.33	mm	2.33mm
L2	27	mm	27mm
W2	3.82	mm	3.82mm

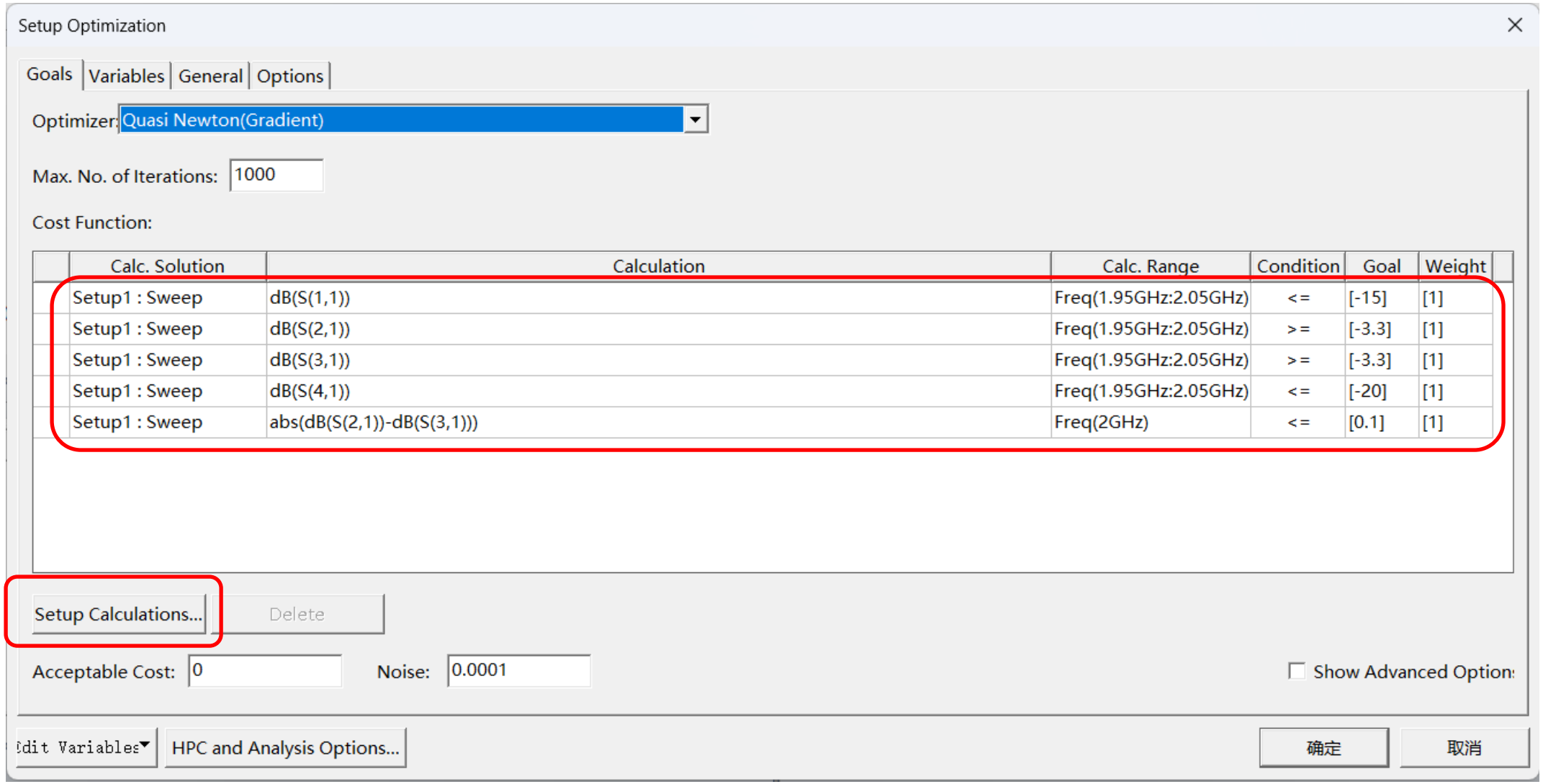

Z
Y
0
30
60 (mm)


S Parameter Plot 1
HFSSDesign1
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(2,1))
Setup1 : Sweep
dB(S(3,1))
Setup1 : Sweep
dB(S(4,1))
Setup1 : Sweep
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
Y1
1.50
1.75
2.00
2.25
2.50
Freq [GHz]
-2.84
-2.85
-2.89
-3.89
-3.50
-16.40
-18.15
-19.79
-21.70
-25.22
-27.01
0.05
2.00
0.05
1.95
2.05

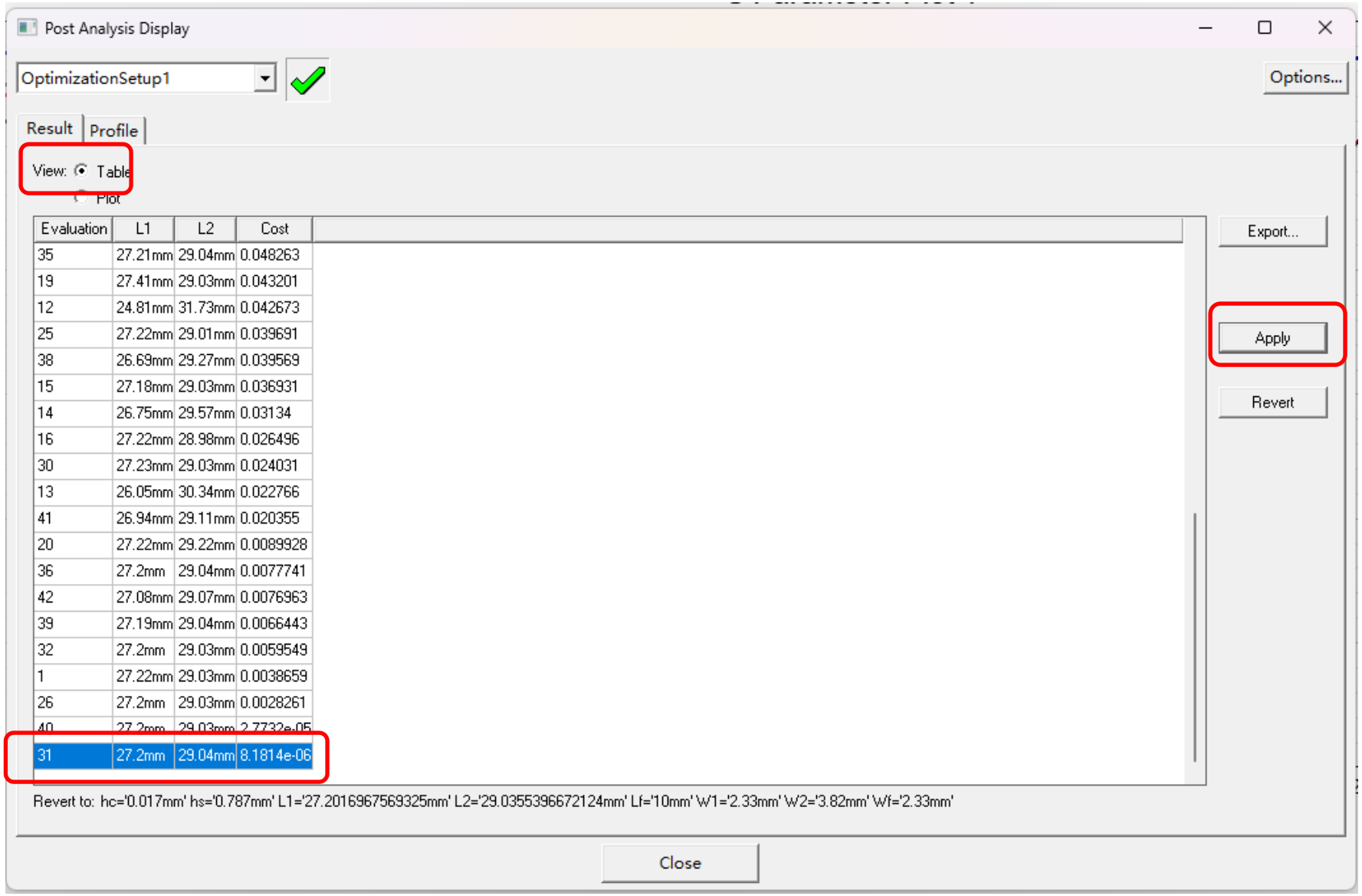

S Parameter Plot 3
HFSSDesign1
Curve Info
dB(S(2,1))-dB(S(3,1))
Setup1 : Sweep
cang_deg(S(2,1))-cang_deg(S(3,1))
Setup1 : Sweep
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
dB(S(2,1))-dB(S(3,1))
87.50
75.00
62.50
cang_deg(S(2,1))-cang_deg(S(3,1)) [deg]
1.50
1.75
2.00
2.25
2.50
Freq [GHz]
-0.61
-0.81
88.10
-1.05
88.95
89.50
0.05
2.00
0.05
1.95
2.05

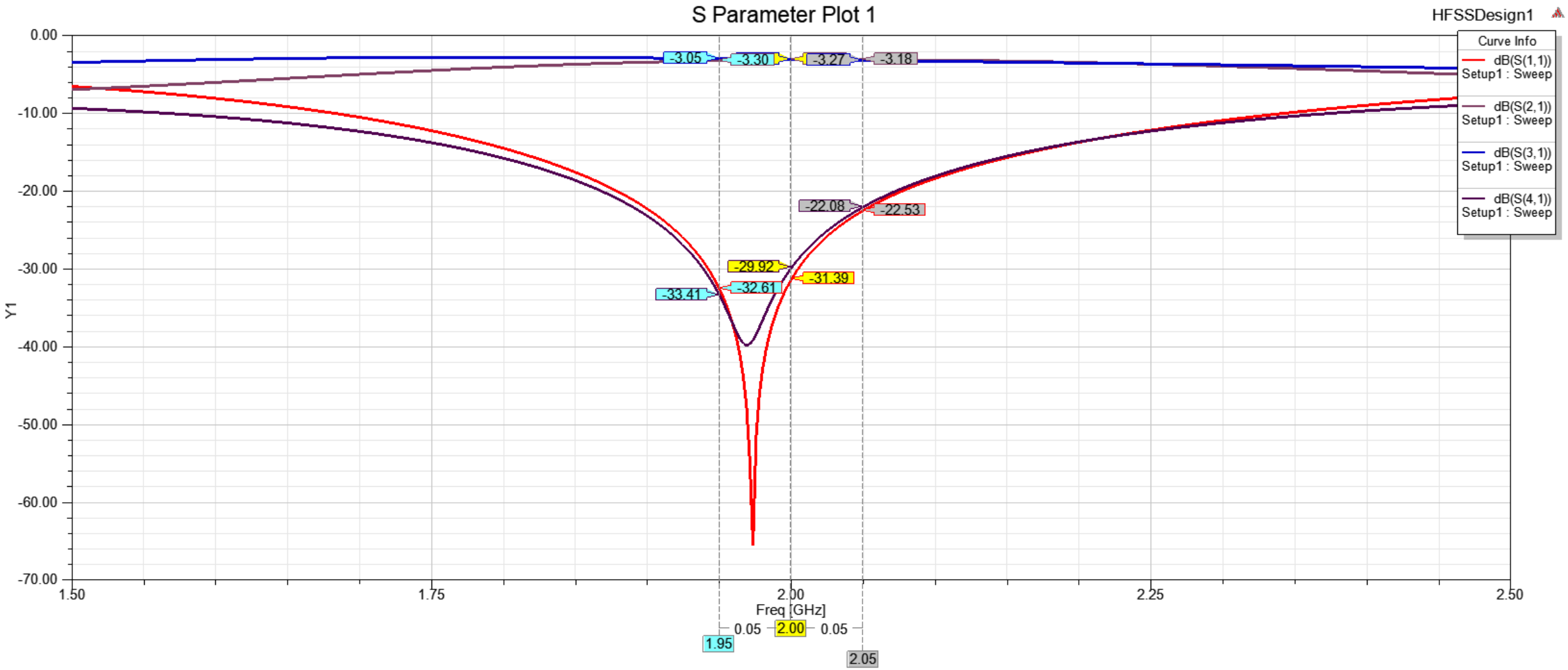

HFSS
Tools
Window
Help
Solution Type...
List...
Validation Check...
Analyze All
Submit Job...
Edit Notes...
Toolkit
3D Model Editor
Set Object Temperature...
Design Settings...
Model
Boundaries
Excitations
Hybrid
Mesh Operations
Analysis Setup
Optimetrics Analysis
Fields
Radiation
Results
Boundary Display (Solver View)
Design Properties...
Design Datasets...
Properties: BranchLineCoupler - HFSSDesign1
Local Variables
Value
Optimization / Design of Exper
Tuning
Sensitivit
Statistics
Name
Inclu...
N...
Min
Unit
Max
Unit
Lf
1...
5
mm
15
mm
L1
2...
13.61
mm
40.83
mm
L2
2...
13.5
mm
40.5
mm
hs
0....
0.3935
mm
1.1805
mm
hc
0....
0.0085
mm
0.0255
mm
Wf
2....
1.165
mm
3.495
mm
W1
2....
1.165
mm
3.495
mm
W2
3....
1.91
mm
5.73
mm
Show Hidden
Add...
Add Array...
Edit...
Remove
确定
取消
应用(A)

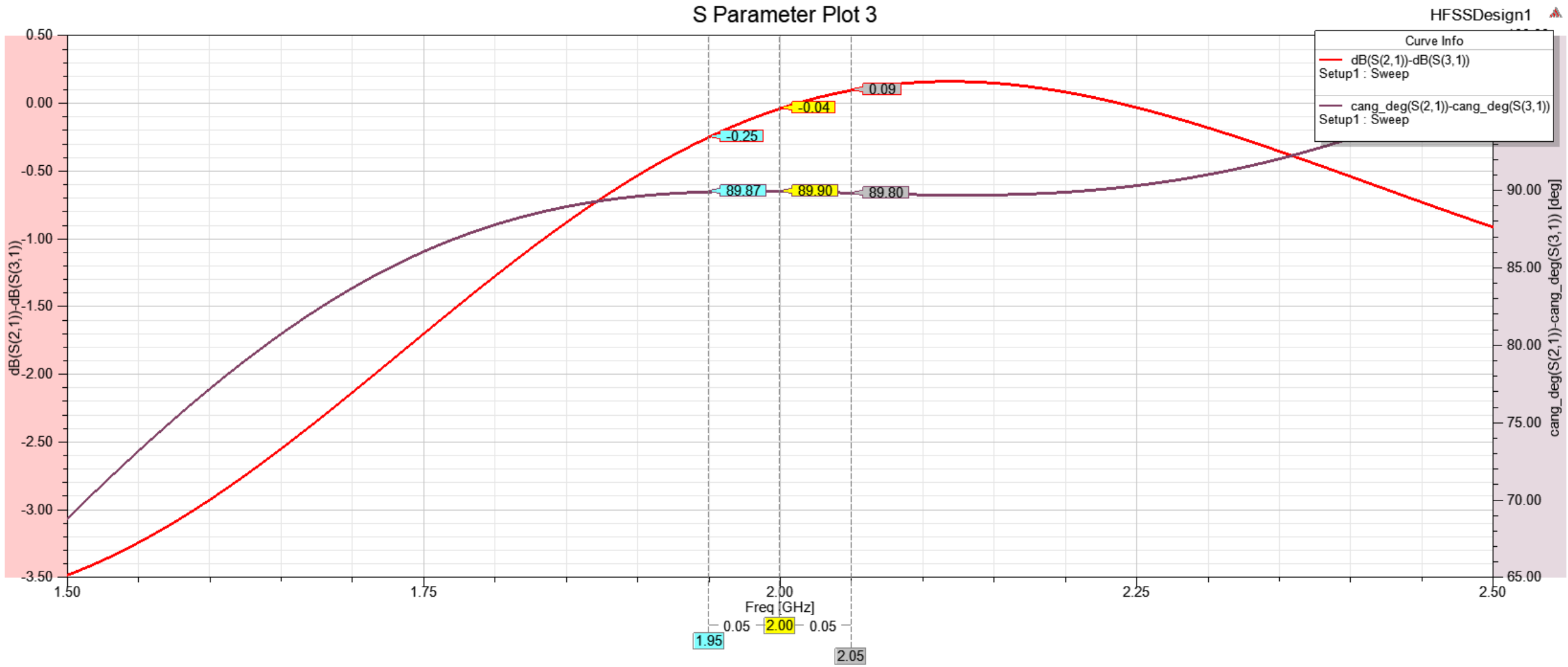
Optimetrics -> Right click -> Add -> Optimization



Optimetrics -> OptimizationSetup1 -> Right Click -> View Analysis Result




S Parameter Plot 1
HFSSDesign1
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(2,1))
Setup1 : Sweep
dB(S(3,1))
Setup1 : Sweep
dB(S(4,1))
Setup1 : Sweep
-3.05
-3.30
-3.27
-3.18
-22.08
-22.53
-29.92
-31.39
-33.41
-32.61
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
Y1
1.50
1.75
2.00
2.25
2.50
Freq [GHz]
0.05
2.00
0.05
1.95
2.05


S Parameter Plot 3
HFSSDesign1
Curve Info
dB(S(2,1))-dB(S(3,1))
Setup1 : Sweep
cang_deg(S(2,1))-cang_deg(S(3,1))
Setup1 : Sweep
0.09
-0.04
-0.25
89.87
89.90
89.80
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
dB(S(2,1))-dB(S(3,1))
90.00
85.00
80.00
75.00
70.00
65.00
cang_deg(S(2,1))-cang_deg(S(3,1)) [deg]
1.50
1.75
2.00
2.25
2.50
Freq [GHz]
0.05
2.00
0.05
1.95
2.05

Homework

- Design a Branch Line Coupler in ADS and HFSS
- Center Frequency: 1.45 GHz
- Bandwidth: 100MHz
- Substrate: FR4, thickness: 1.6mm
- S11<-15dB, S21>-3.3dB, S31>-3.3dB, S41<-20dB
- abs(S31-S21)<0.1dB at center frequency
- 89°<|phase(S31)-phase(S21)|<91° at center frequency
- Optimization