SUSTech Southern University of Science and Technology

Microwave Engineering (Lab)

Lab 7: Design of Microstrip Patch Antenna

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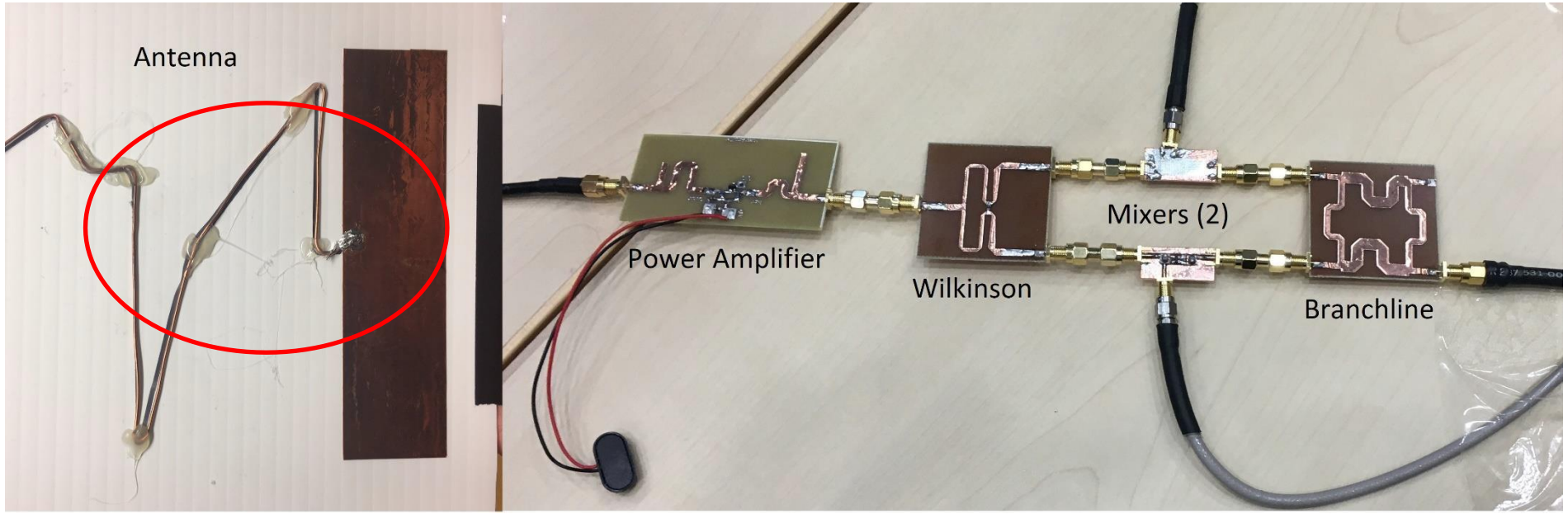
Bits2Waves, a 1-day experience on building your own modern digital radio.



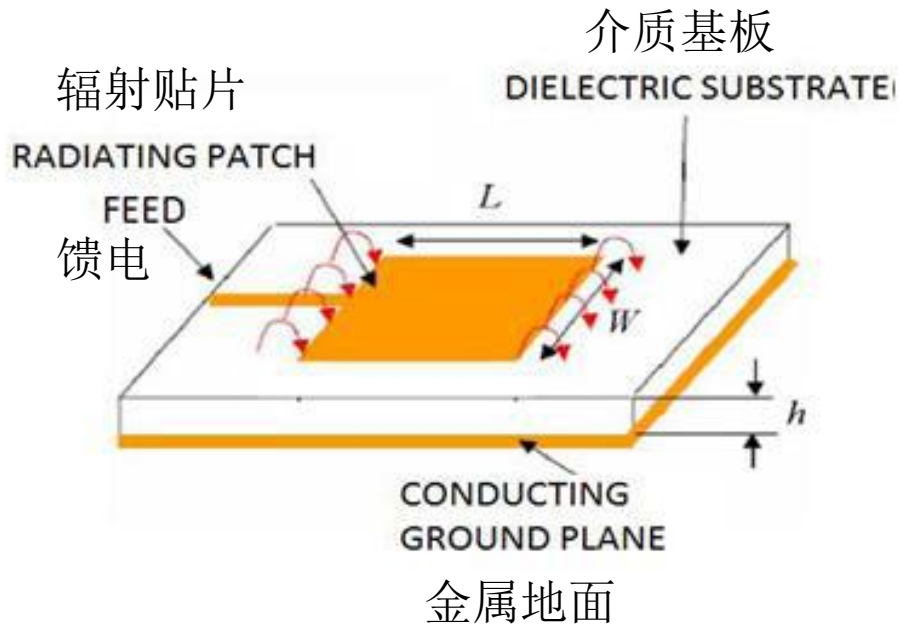
https://rickettslab.org/bits2waves/bits2waves-download/

天线

天线是一种变换器，它把传输线上传播的导行波，变换成在预定方向上辐射的空间电磁波，或者进行相反的变换。

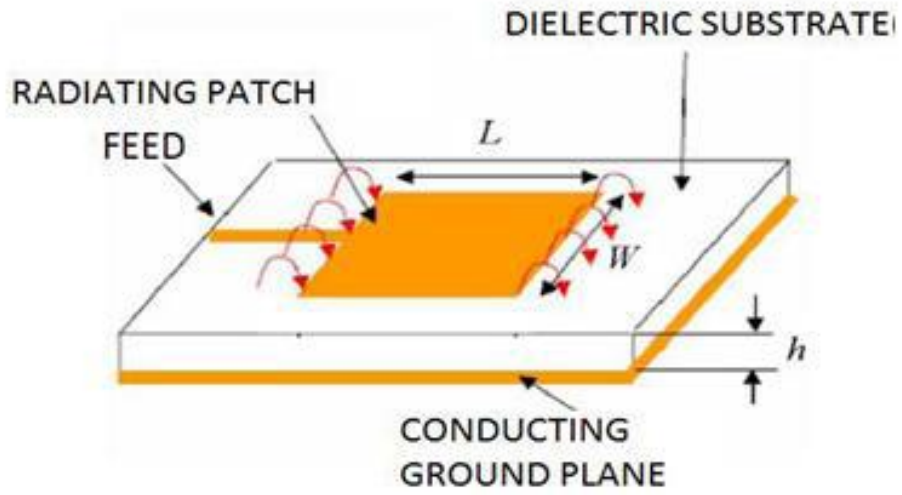
辐射原理

The patch acts as a resonant cavity.



设计一个微带贴片天线

1. 基板FR4，厚度1.6mm
2. 中心频率：2.4GHz
3. 端口阻抗50Ω
4. 带宽：50MHz
5. S11<-10dB



- 选择介质基板，估算出辐射贴片的尺寸。
- 设介质基板的介电常数为ε_r，矩形微带天线工作频率为f，光速为c，辐射贴片的宽度W根据下式确定：

$$\mathrm{W}=\frac{c}{2f}\left(\frac{\varepsilon_r+1}{2}\right)^{-\frac{1}{2}}$$

- 辐射贴片的长度一般为$\lambda_{\mathrm{g}}/2$，λ_{g}是介质内的导波波长，　　$\lambda_{\mathrm{g}}=\frac{c}{f\sqrt{\varepsilon_e}}$

- 考虑到边缘缩短效应后，实际的辐射贴片长度L为，

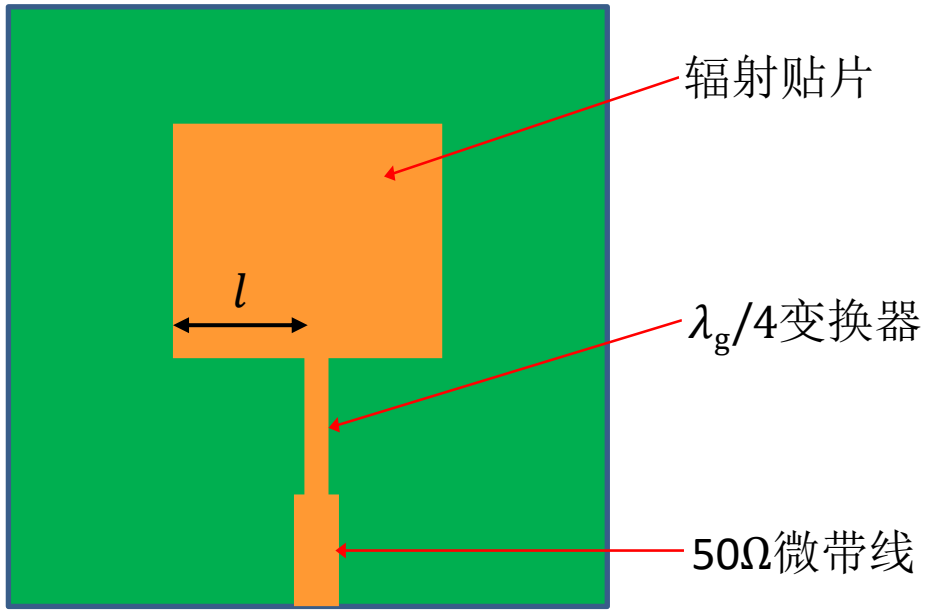
$$L=\frac{c}{2f\sqrt{\varepsilon_e}}-2\Delta L$$

式子中，ε_{e}是等效介电常数，ΔL是等效辐射缝隙长度，分别可以用下式计算：

$$\varepsilon_{\mathrm{e}}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{\mathrm{W}}\right)^{-\frac{1}{2}}$$

$$\Delta L=0.412h\frac{(\varepsilon_{\mathrm{e}}+0.3)(\mathrm{W}/h+0.264)}{(\varepsilon_{\mathrm{e}}-0.258)(\mathrm{W}/h+0.8)}$$

馈电



- 辐射贴片输入导纳公式：

$$Y_{in}(l) = 2G\left[\cos^2(\beta l) + \frac{G^2 + B^2}{Y_0^2}\sin^2(\beta l) - \frac{B}{Y_0}\sin(2\beta l)\right]^{-1}$$

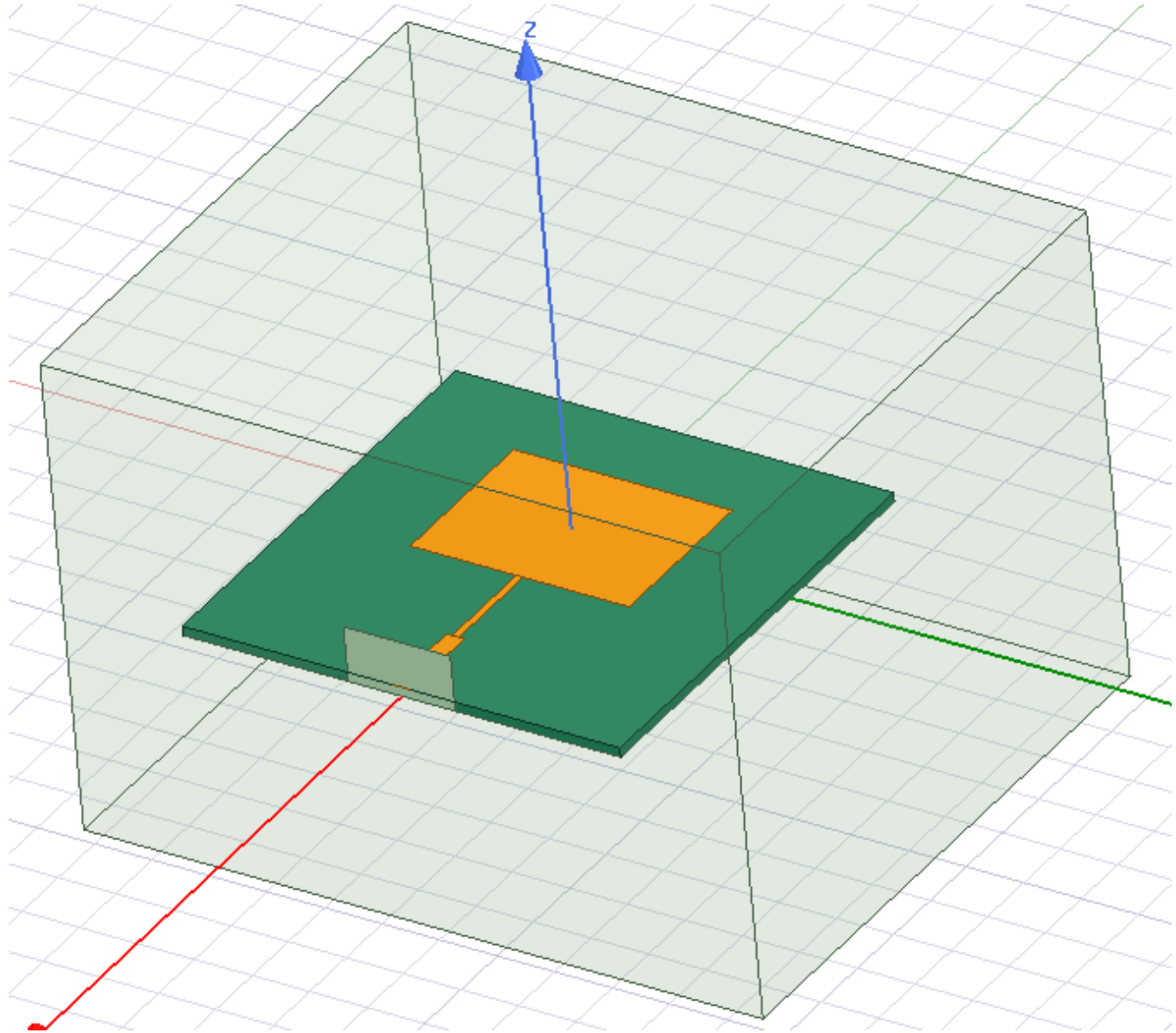
- 其中，

Y_0为将天线视为传输线时的特性导纳

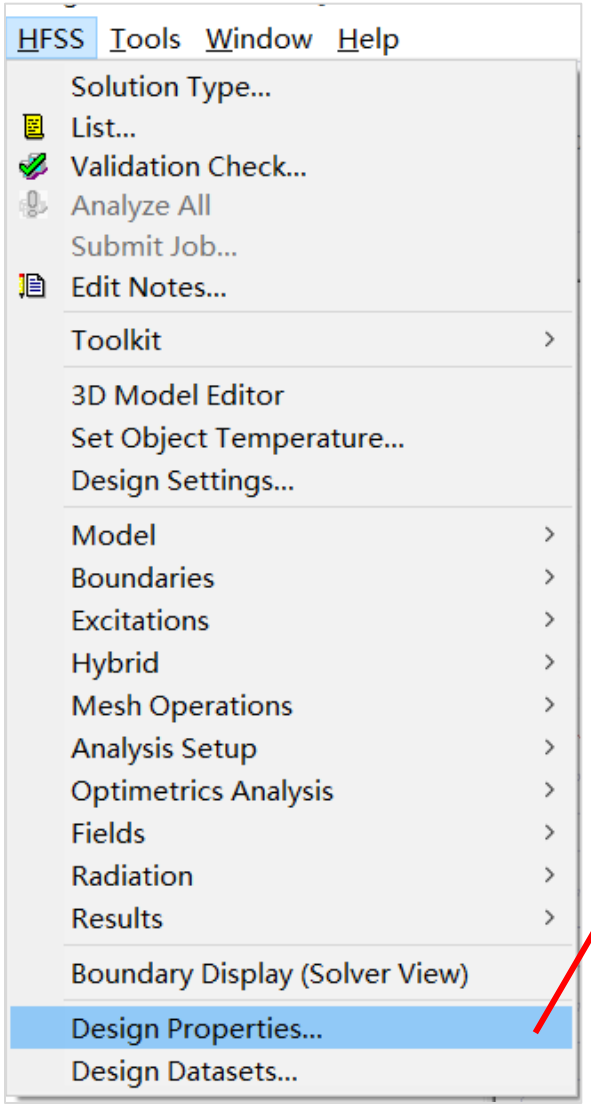
l为馈线到天线边缘的距离

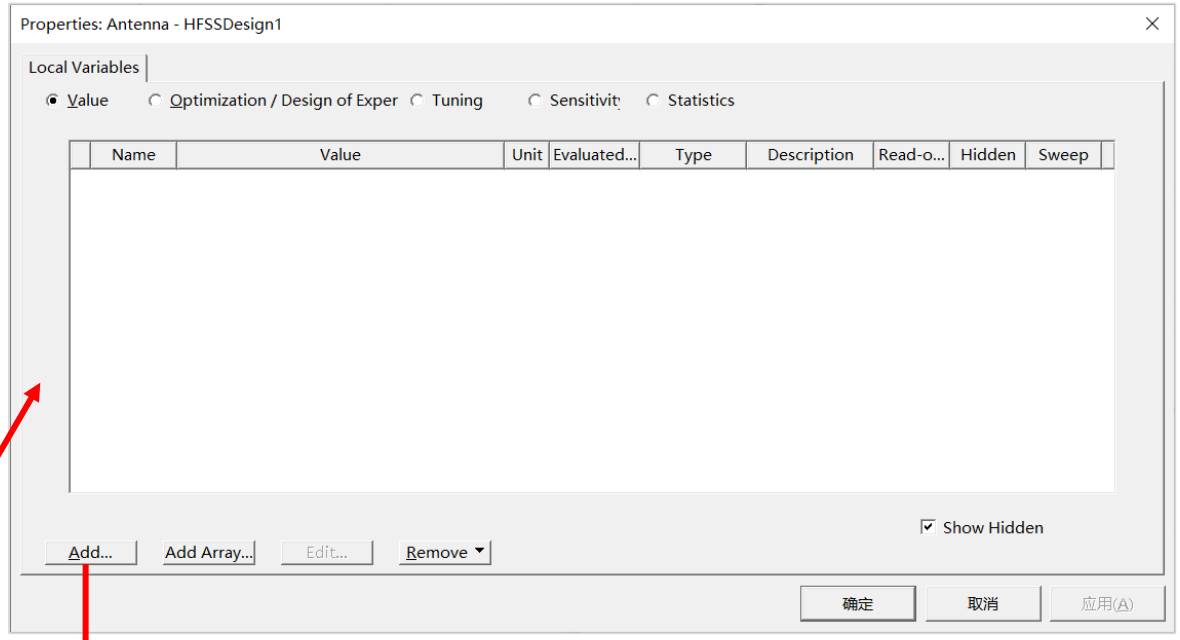
$$G = \frac{I}{120\pi^2} \qquad B = \frac{k\Delta L\sqrt{\varepsilon_e}}{Z_0}$$

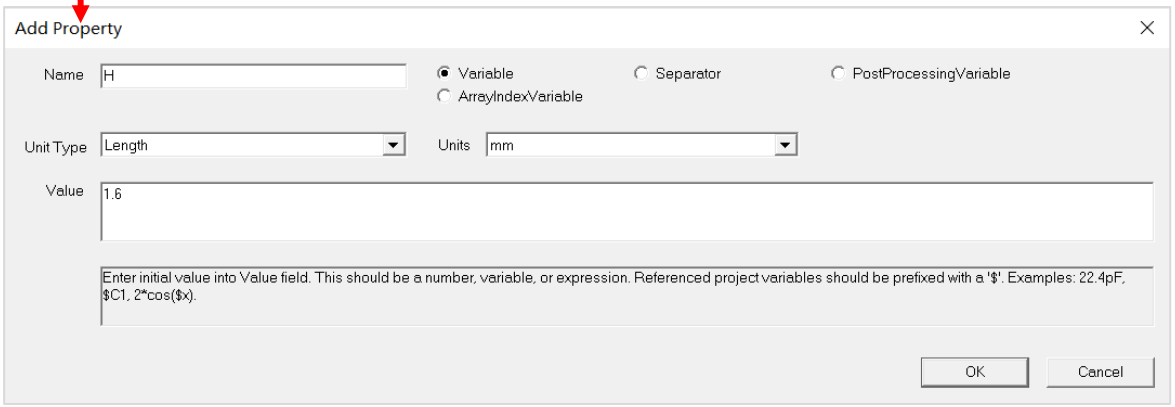
$$I = \int_0^{\pi} \sin^2\left(\frac{kW}{2}\cos\theta\right)\tan^2\theta\sin\theta\, d\theta$$


z

定义变量


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: Antenna - HFSSDesign1
Local Variables
Value
Optimization / Design of Exper
Tuning
Sensitivity
Statistics
Name
Value
Unit
Evaluated...
Type
Description
Read-o...
Hidden
Sweep
Show Hidden
Add...
Add Array...
Edit...
Remove
确定
取消
应用(A)


Add Property
Name
H
Variable
Separator
PostProcessingVariable
ArrayIndexVariable
Unit Type
Length
Units
mm
Value
1.6
Enter initial value into Value field. This should be a number, variable, or expression. Referenced project variables should be prefixed with a '$'. Examples: 22.4pF, $C1, 2*cos($x).
OK
Cancel

Properties: PatchAntenna - HFSSDesign1

Local Variables

Value | Optimization / Design of Exper | Tuning | Sensitivit | Statistics

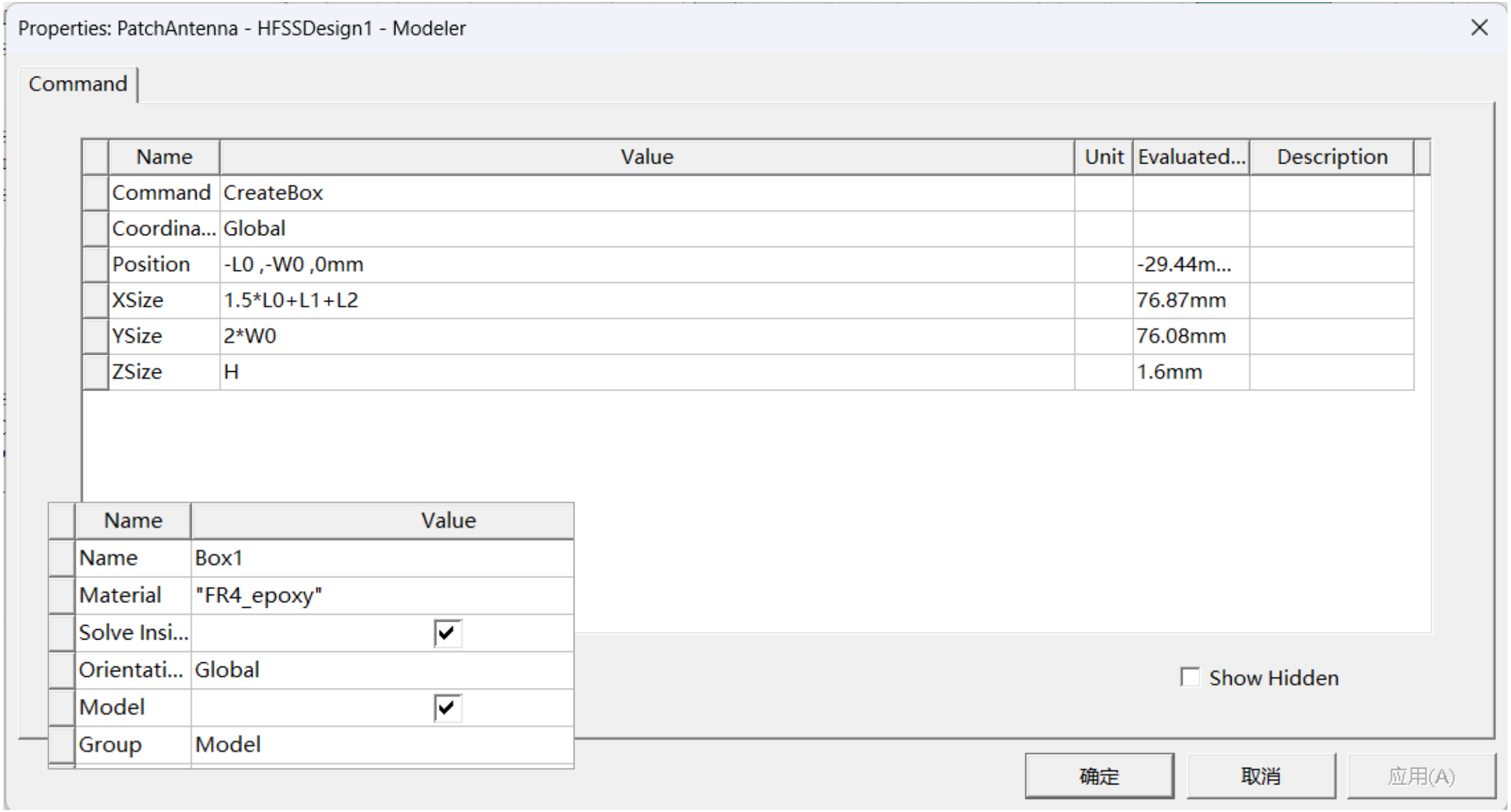
	Name	Value	Unit	Evaluated...	Type	Description	Read-o...	Hidden	Sweep
	Substrate								
	H	1.6	mm	1.6mm	Design		☐	☐	☑
	Patch								
	W0	38.04	mm	38.04mm	Design		☐	☐	☑
	L0	28.5	mm	28.5mm	Design		☐	☐	☑
	QuaterWavelengthLine								
	W1	1.2	mm	1.2mm	Design		☐	☐	☑
	L1	17.71	mm	17.71mm	Design		☐	☐	☑
	FeedLine								
	W2	3.1	mm	3.1mm	Design		☐	☐	☑
	L2	15	mm	15mm	Design		☐	☐	☑

☑ Show Hidden

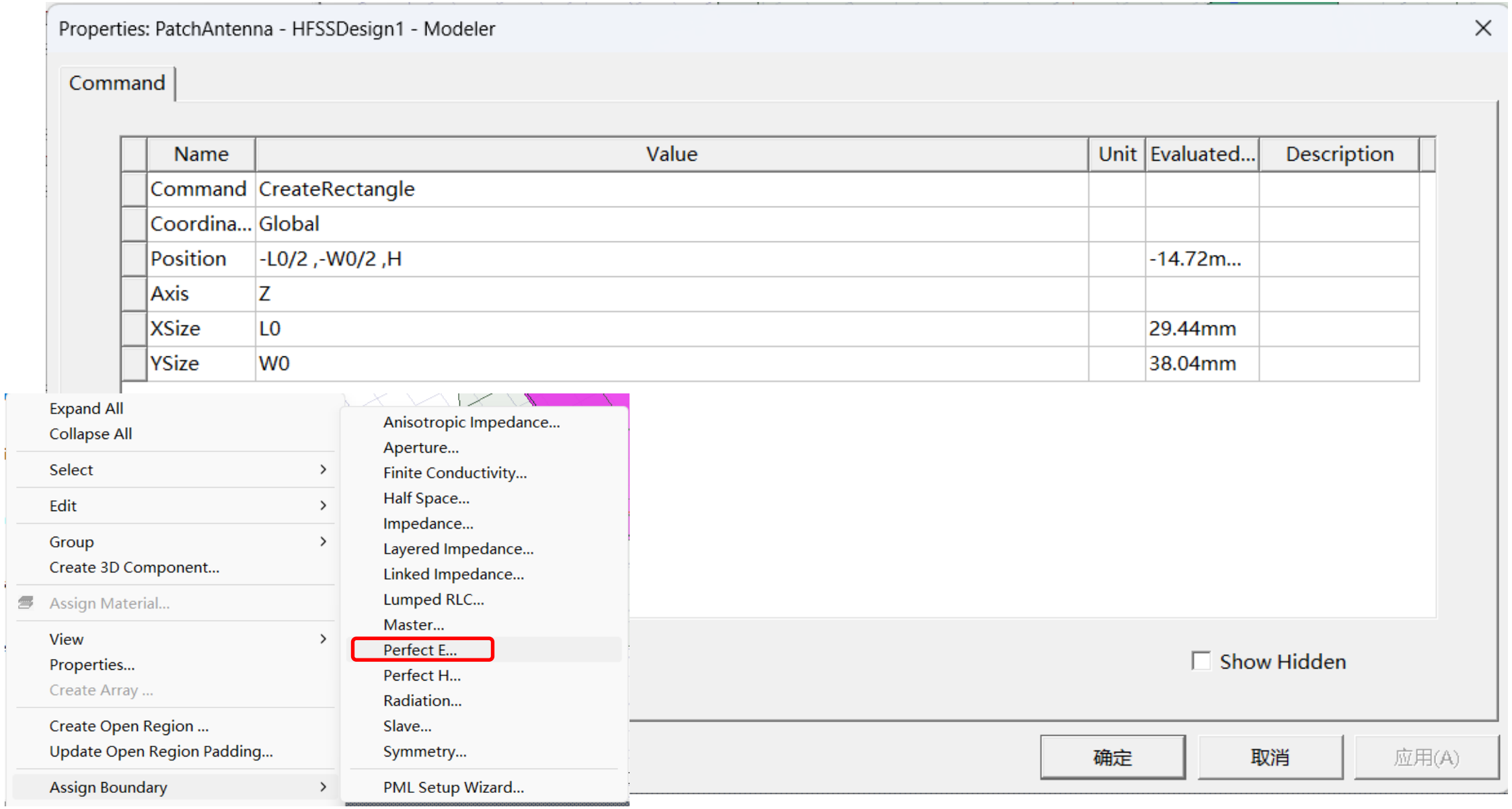
Add... | Add Array... | Edit... | Remove

确定 | 取消 | 应用(A)

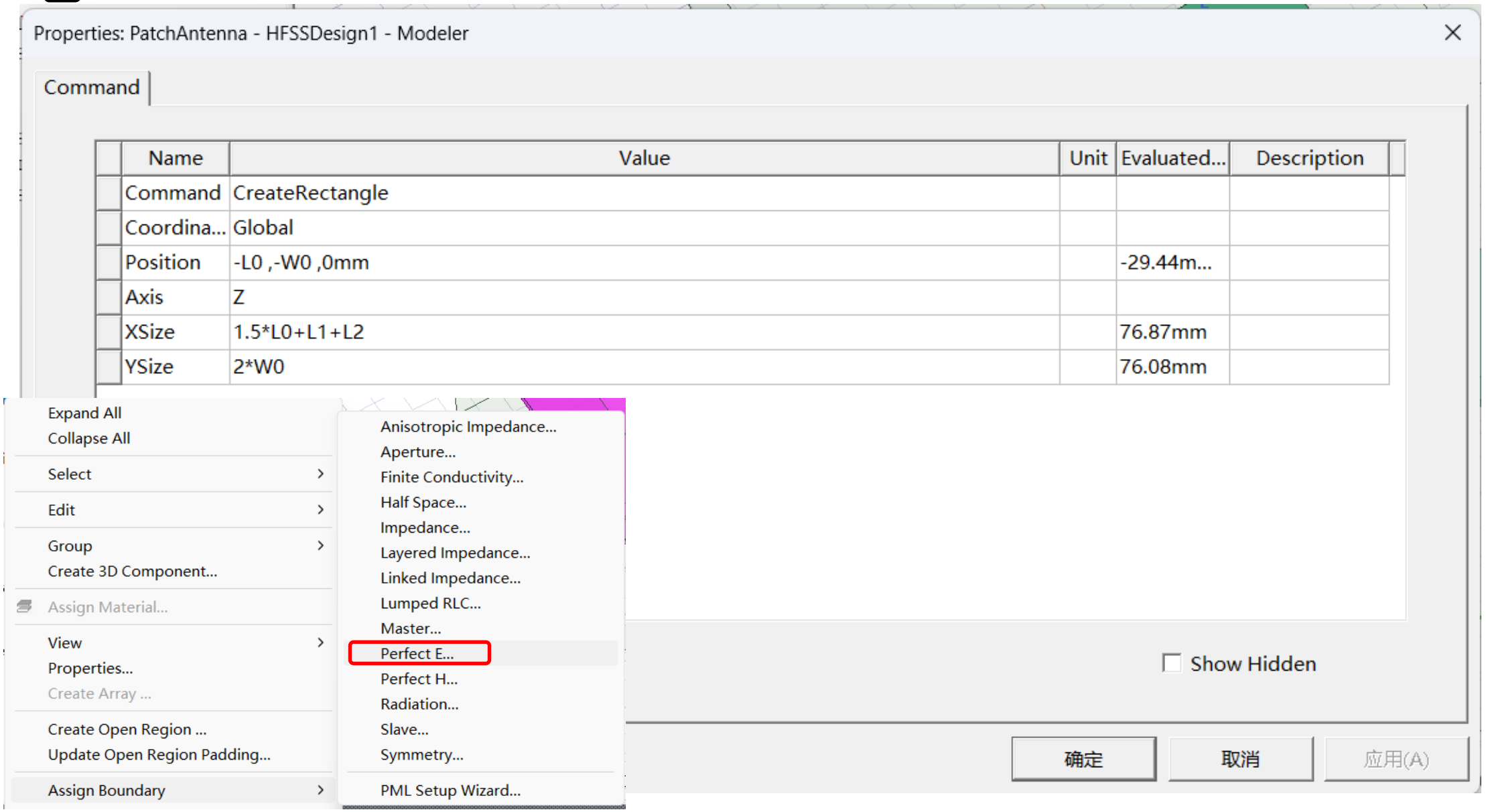
介质基板


Properties: PatchAntenna - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated...
Description
Command
CreateBox
Coordina...
Global
Position
-L0 ,-W0 ,0mm
-29.44m...
XSize
1.5*L0+L1+L2
76.87mm
YSize
2*W0
76.08mm
ZSize
H
1.6mm
Name
Value
Name
Box1
Material
"FR4_epoxy"
Solve Insi...
Orientati...
Global
Model
Group
Model
Show Hidden
确定
取消
应用(A)

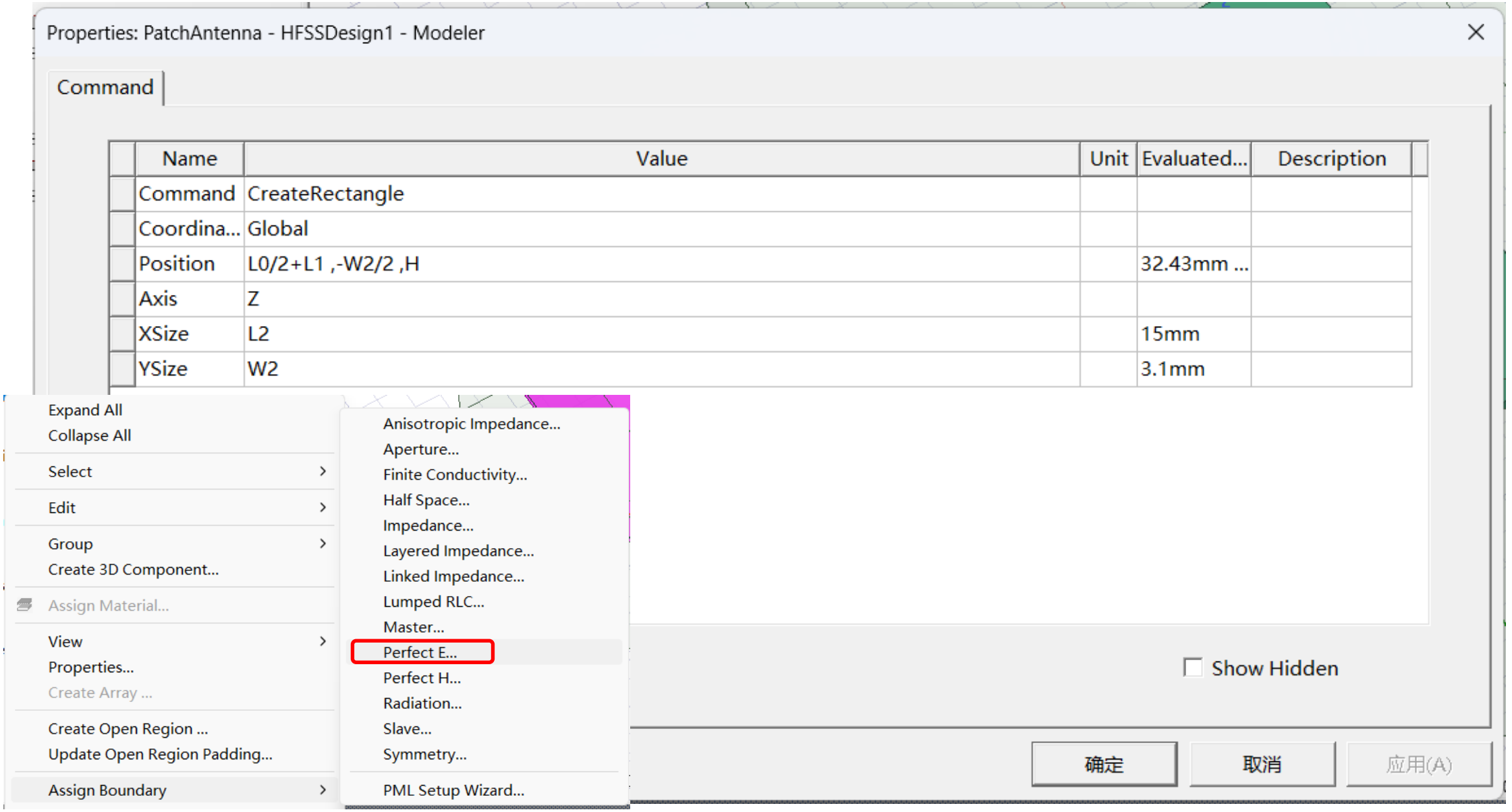
辐射贴片


Properties: PatchAntenna - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated...
Description
Command
CreateRectangle
Coordina...
Global
Position
-L0/2 ,-W0/2 ,H
-14.72m...
Axis
Z
XSize
L0
29.44mm
YSize
W0
38.04mm
Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Anisotropic Impedance...
Aperture...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Master...
Perfect E...
Perfect H...
Radiation...
Slave...
Symmetry...
PML Setup Wizard...
Show Hidden
确定
取消
应用(A)

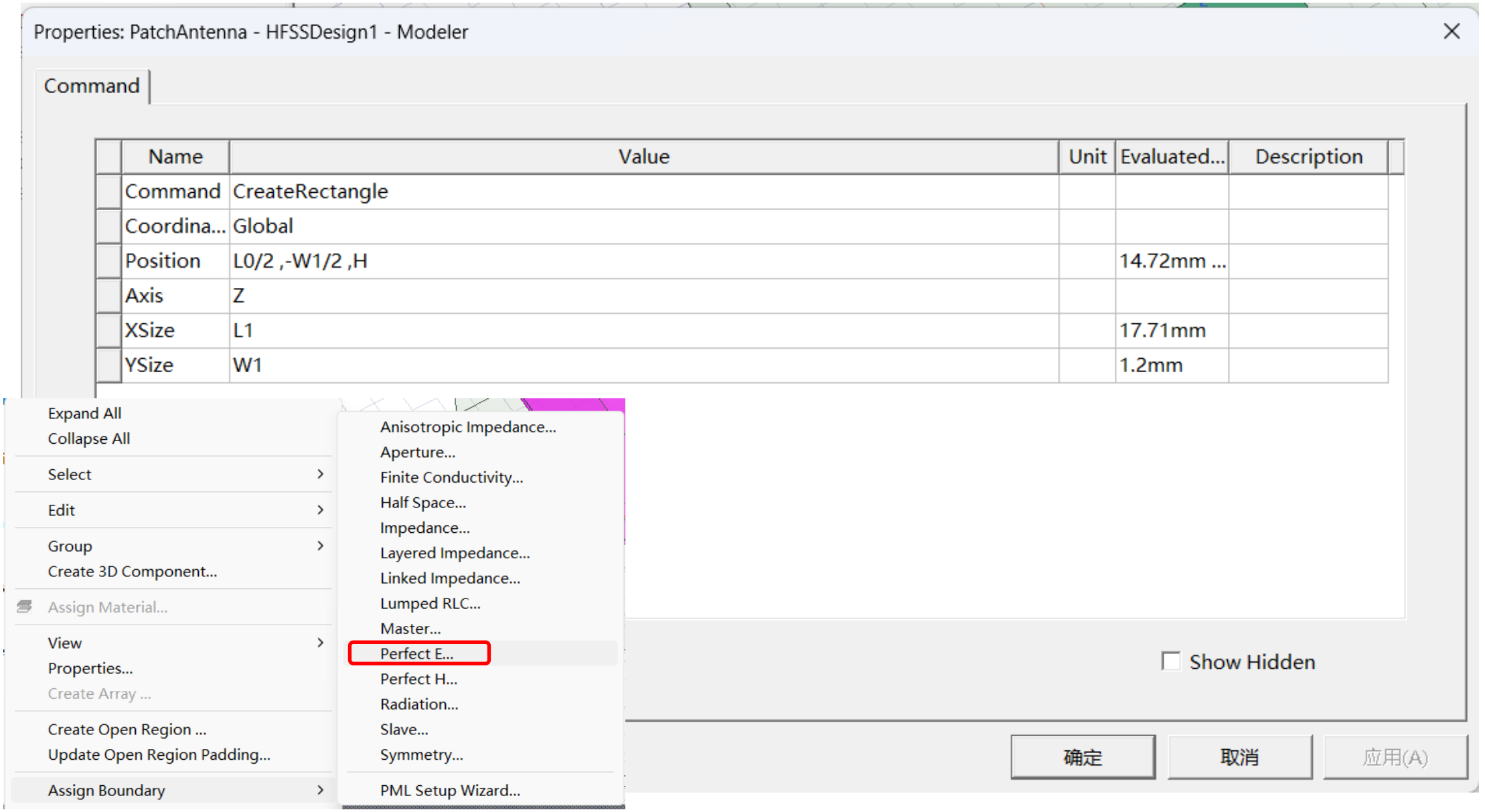
地


Properties: PatchAntenna - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated...
Description
Command
CreateRectangle
Coordina...
Global
Position
-L0 ,-W0 ,0mm
-29.44m...
Axis
Z
XSize
1.5*L0+L1+L2
76.87mm
YSize
2*W0
76.08mm
Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Anisotropic Impedance...
Aperture...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Master...
Perfect E...
Perfect H...
Radiation...
Slave...
Symmetry...
PML Setup Wizard...
Show Hidden
确定
取消
应用(A)

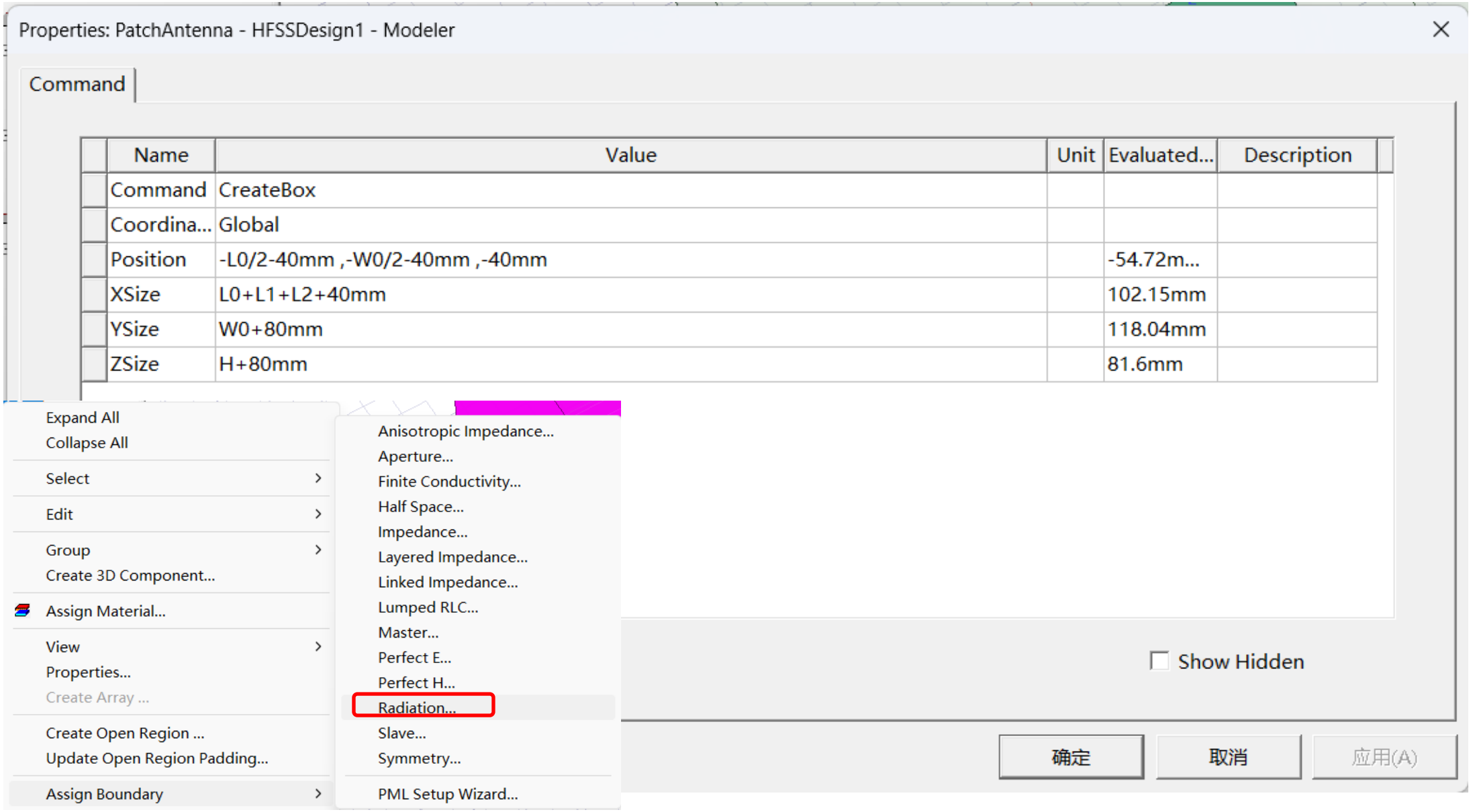
馈电微带


Properties: PatchAntenna - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated...
Description
Command
CreateRectangle
Coordina...
Global
Position
L0/2+L1 ,-W2/2 ,H
32.43mm ...
Axis
Z
XSize
L2
15mm
YSize
W2
3.1mm
Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Anisotropic Impedance...
Aperture...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Master...
Perfect E...
Perfect H...
Radiation...
Slave...
Symmetry...
PML Setup Wizard...
Show Hidden
确定
取消
应用(A)

阻抗变换


Properties: PatchAntenna - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated...
Description
Command
CreateRectangle
Coordina...
Global
Position
L0/2 ,-W1/2 ,H
14.72mm ...
Axis
Z
XSize
L1
17.71mm
YSize
W1
1.2mm
Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Anisotropic Impedance...
Aperture...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Master...
Perfect E...
Perfect H...
Radiation...
Slave...
Symmetry...
PML Setup Wizard...
Show Hidden
确定
取消
应用(A)

辐射边界

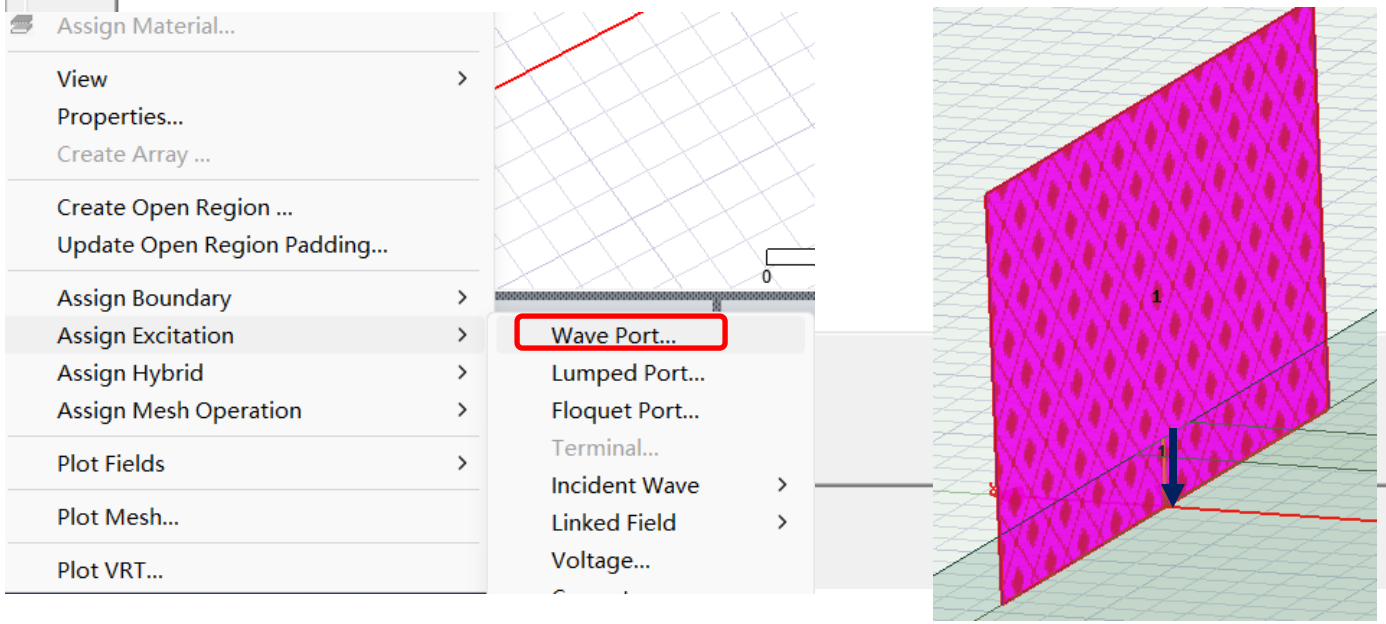

Properties: PatchAntenna - HFSSDesign1 - Modeler
Command
Name
Value
Unit
Evaluated...
Description
Command
CreateBox
Coordina...
Global
Position
-L0/2-40mm ,-W0/2-40mm ,-40mm
-54.72m...
XSize
L0+L1+L2+40mm
102.15mm
YSize
W0+80mm
118.04mm
ZSize
H+80mm
81.6mm
Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Anisotropic Impedance...
Aperture...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Master...
Perfect E...
Perfect H...
Radiation...
Slave...
Symmetry...
PML Setup Wizard...
Show Hidden
确定
取消
应用(A)

波端口

Properties: PatchAntenna - HFSSDesign1 - Modeler

Command

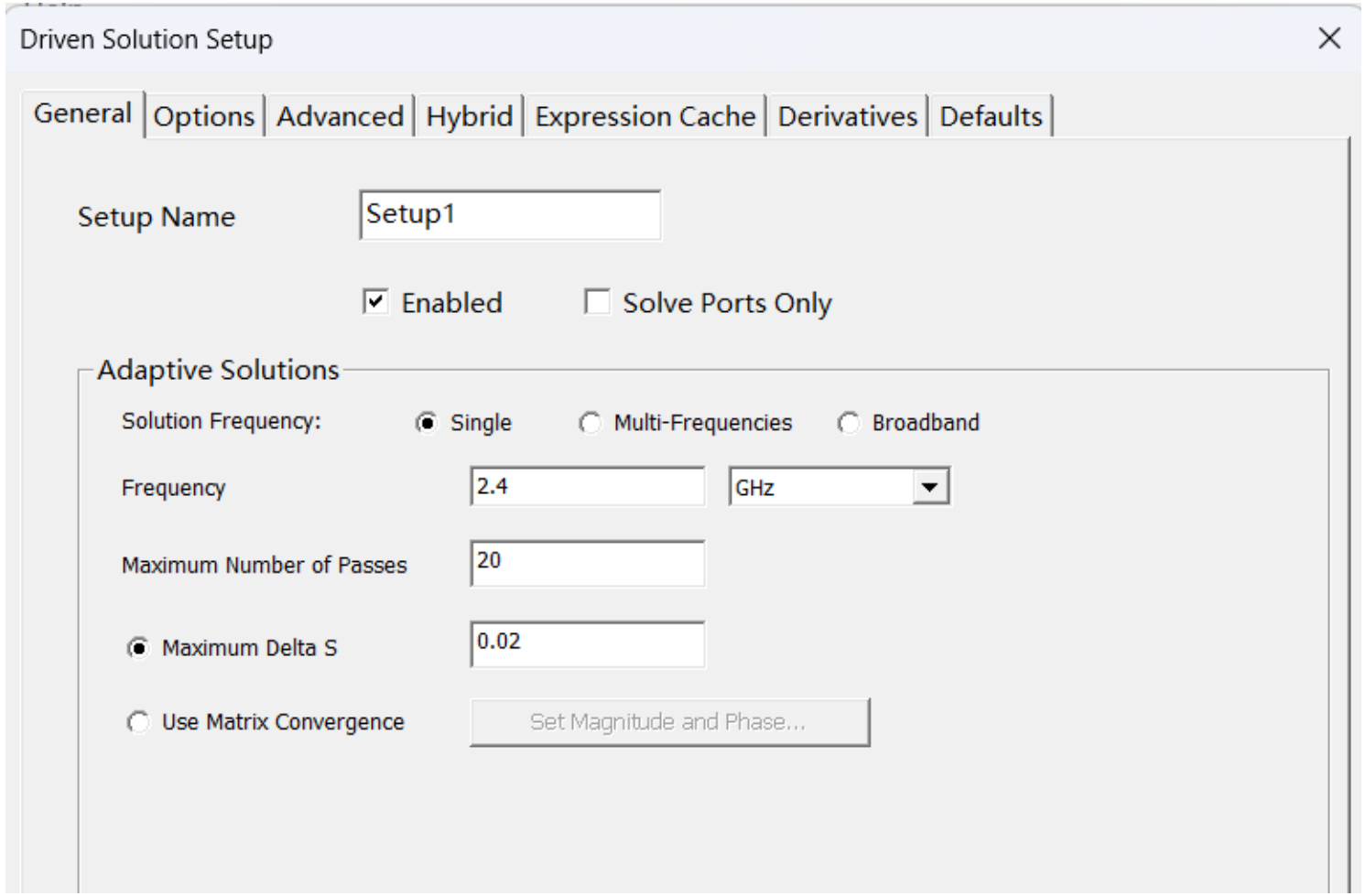
	Name	Value	Unit	Evaluated...	Description
	Command	CreateRectangle			
	Coordina...	Global			
	Position	L0/2+L1+L2 ,-3*W2 ,0mm		47.43mm ...	
	Axis	X			
	YSize	6*W2		18.6mm	
	ZSize	6*H		9.6mm	



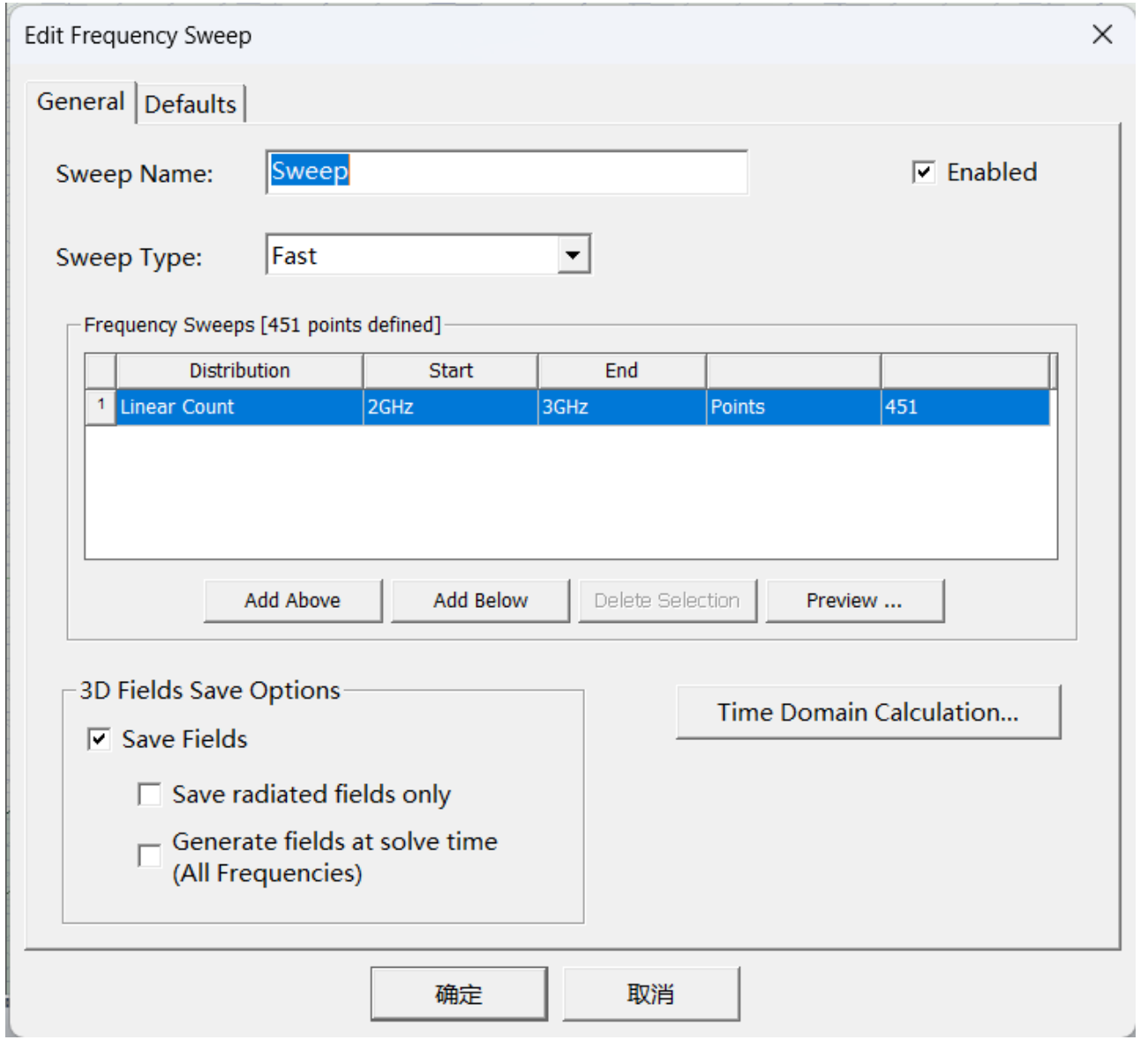
Show Hidden

确定 取消 应用(A)

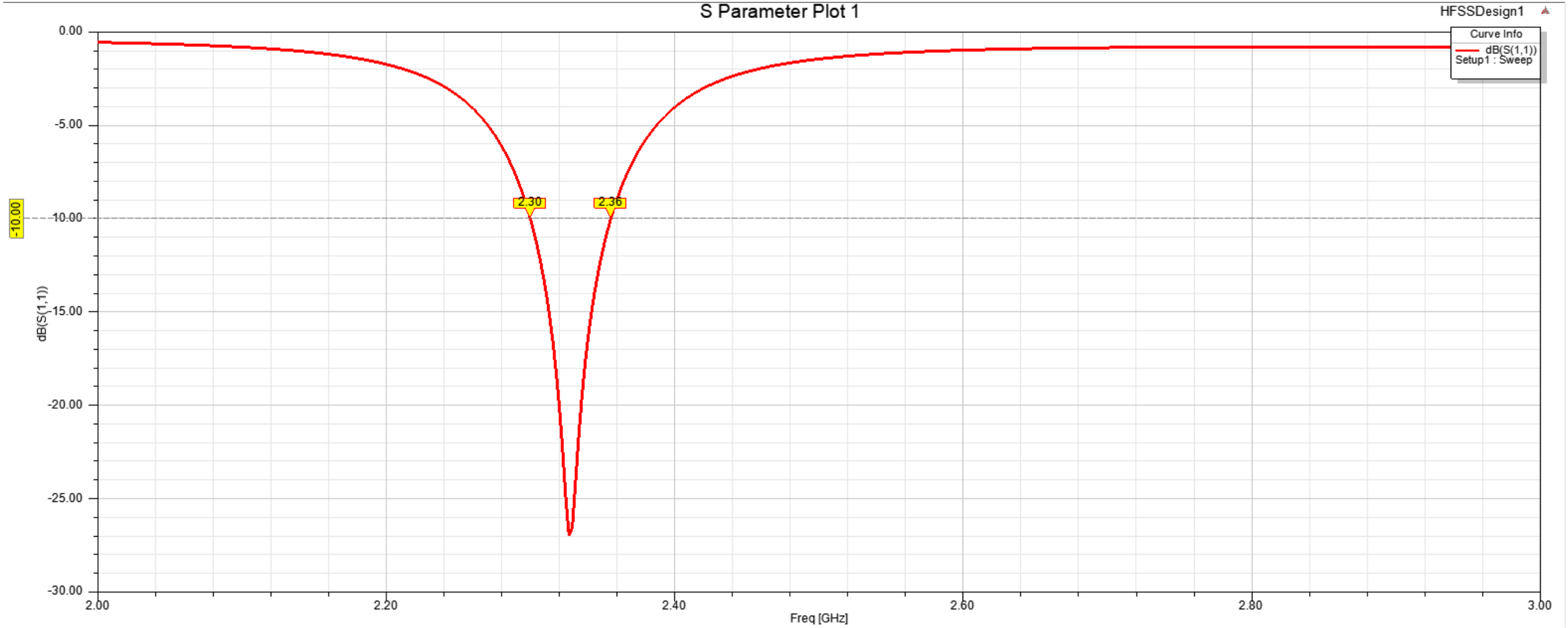
仿真设置


Driven Solution Setup
General
Options
Advanced
Hybrid
Expression Cache
Derivatives
Defaults
Setup Name
Setup1
Enabled
Solve Ports Only
Adaptive Solutions
Solution Frequency:
Single
Multi-Frequencies
Broadband
Frequency
2.4
GHz
Maximum Number of Passes
20
Maximum Delta S
0.02
Use Matrix Convergence
Set Magnitude and Phase...

扫频设置

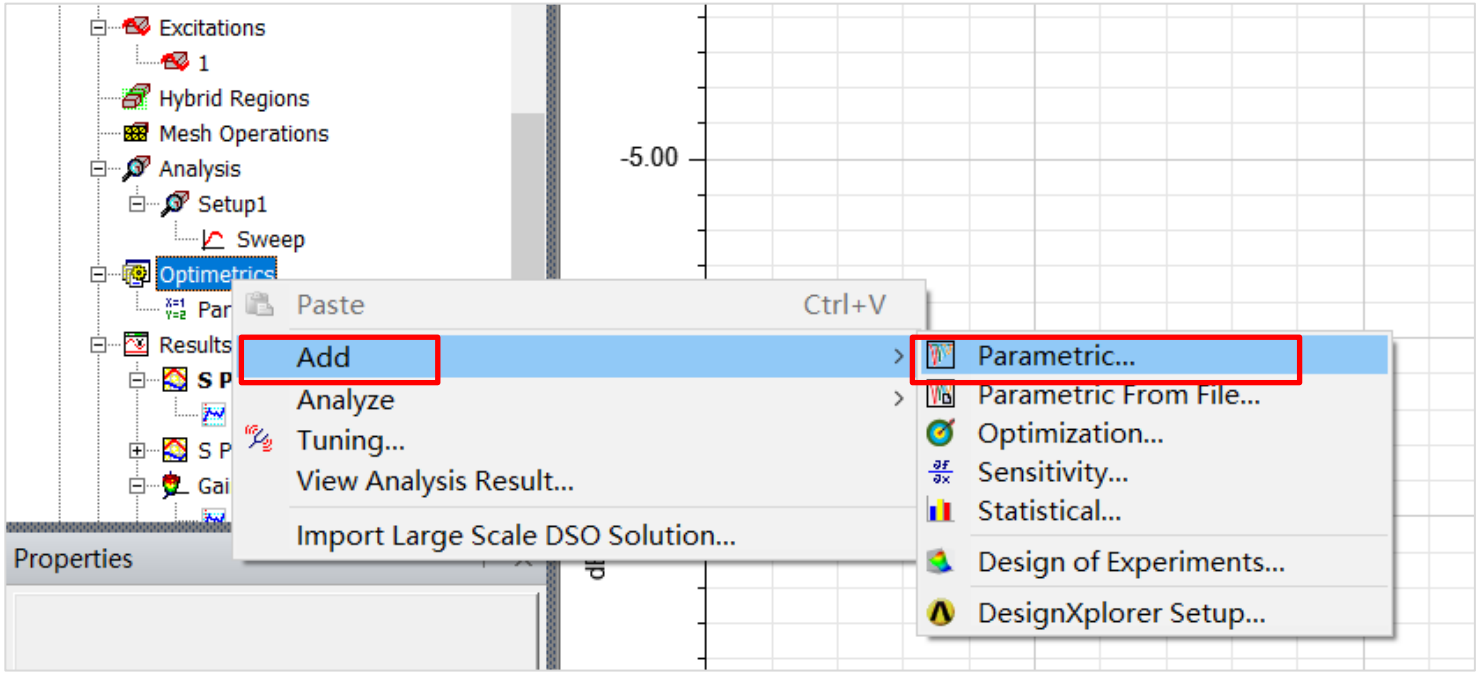

Edit Frequency Sweep
General
Defaults
Sweep Name:
Sweep
Enabled
Sweep Type:
Fast
Frequency Sweeps [451 points defined]
Distribution
Start
End
1
Linear Count
2GHz
3GHz
Points
451
Add Above
Add Below
Delete Selection
Preview ...
3D Fields Save Options
Save Fields
Save radiated fields only
Generate fields at solve time
(All Frequencies)
Time Domain Calculation...
确定
取消

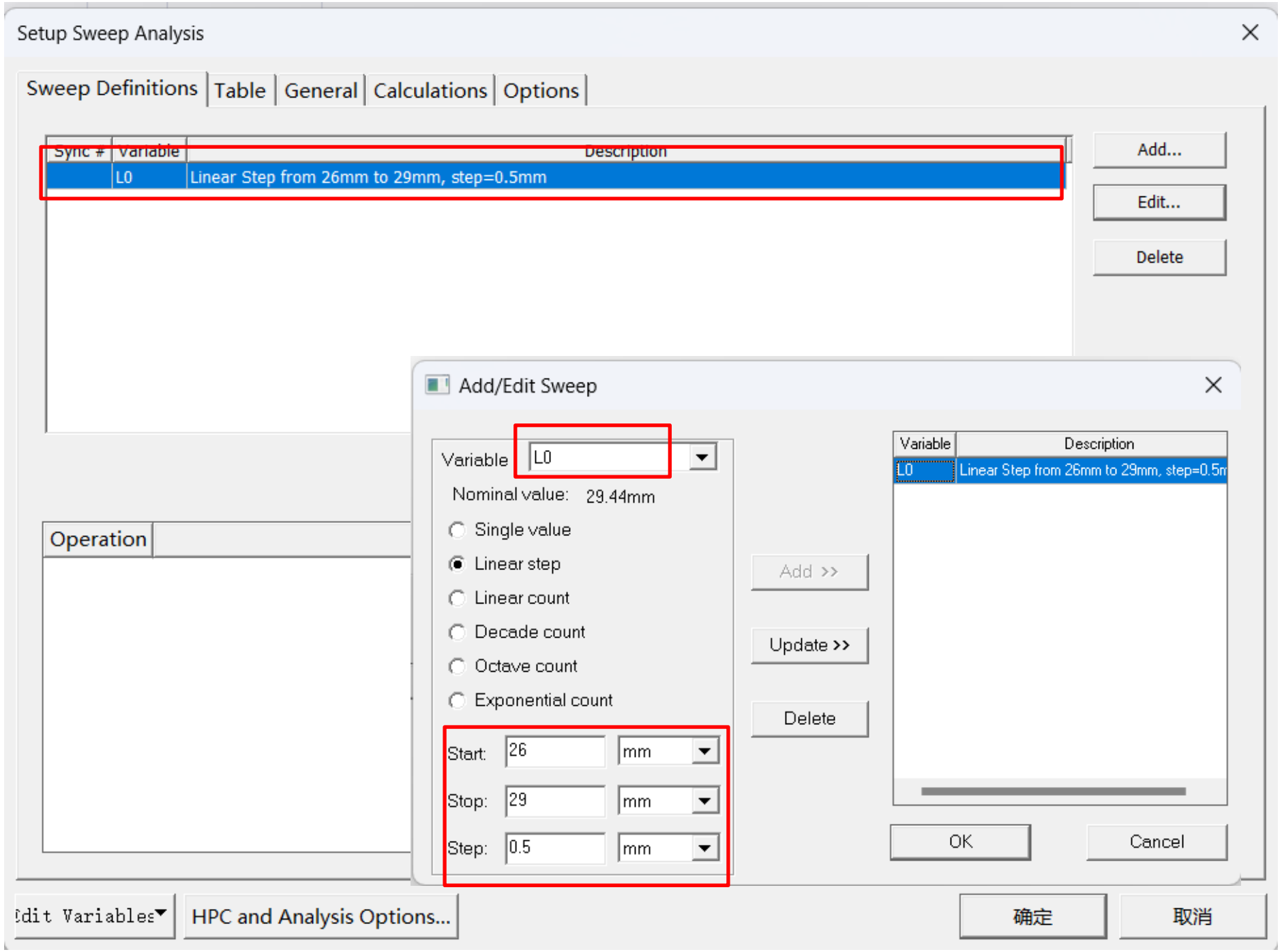
仿真结果


S Parameter Plot 1
HFSSDesign1
Curve Info
dB(S(1,1))
Setup1 : Sweep
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
dB(S(1,1))
-10.00
2.30
2.36
2.00
2.20
2.40
2.60
2.80
3.00
Freq [GHz]

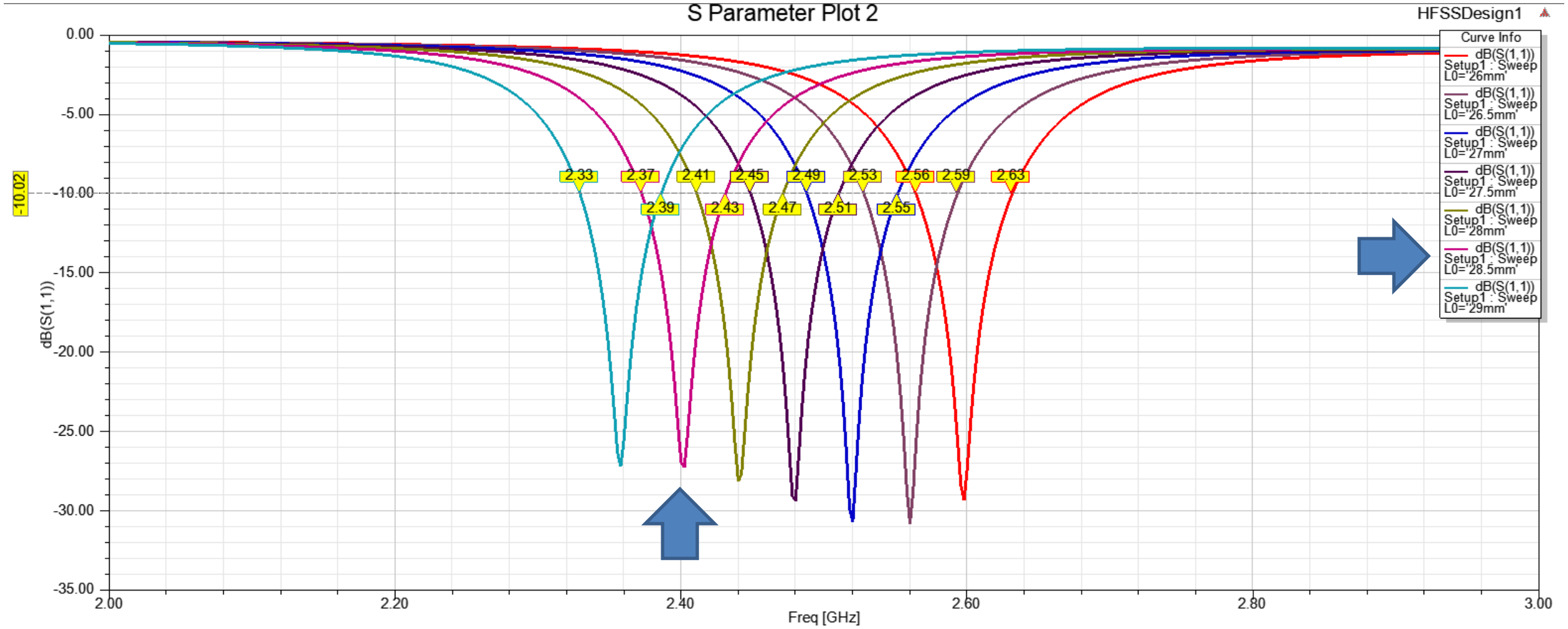
扫参设置

Right Click on Optimetrics



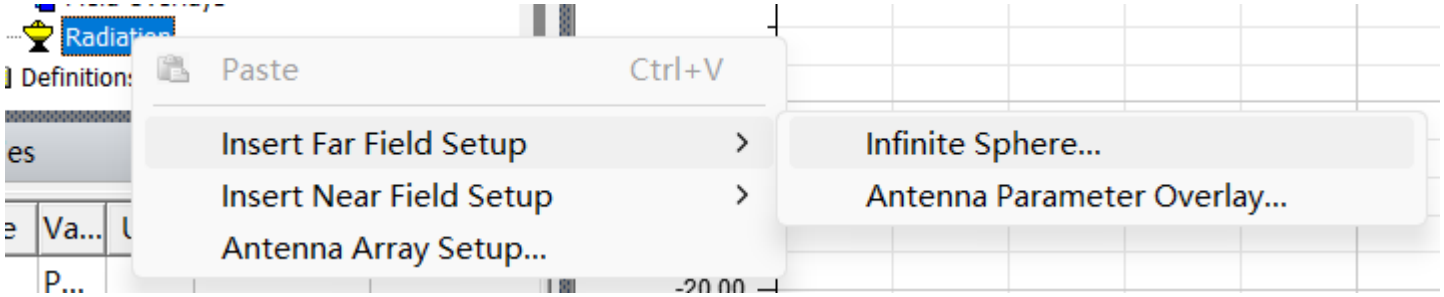

Setup Sweep Analysis
Sweep Definitions
Table
General
Calculations
Options
Sync #
Variable
Description
L0
Linear Step from 26mm to 29mm, step=0.5mm
Add...
Edit...
Delete
Operation
Add/Edit Sweep
Variable
L0
Nominal value:
29.44mm
Single value
Linear step
Linear count
Decade count
Octave count
Exponential count
Start:
26
mm
Stop:
29
mm
Step:
0.5
mm
Add >>
Update >>
Delete
Variable
Description
L0
Linear Step from 26mm to 29mm, step=0.5m
OK
Cancel
Edit Variables
HPC and Analysis Options...
确定
取消

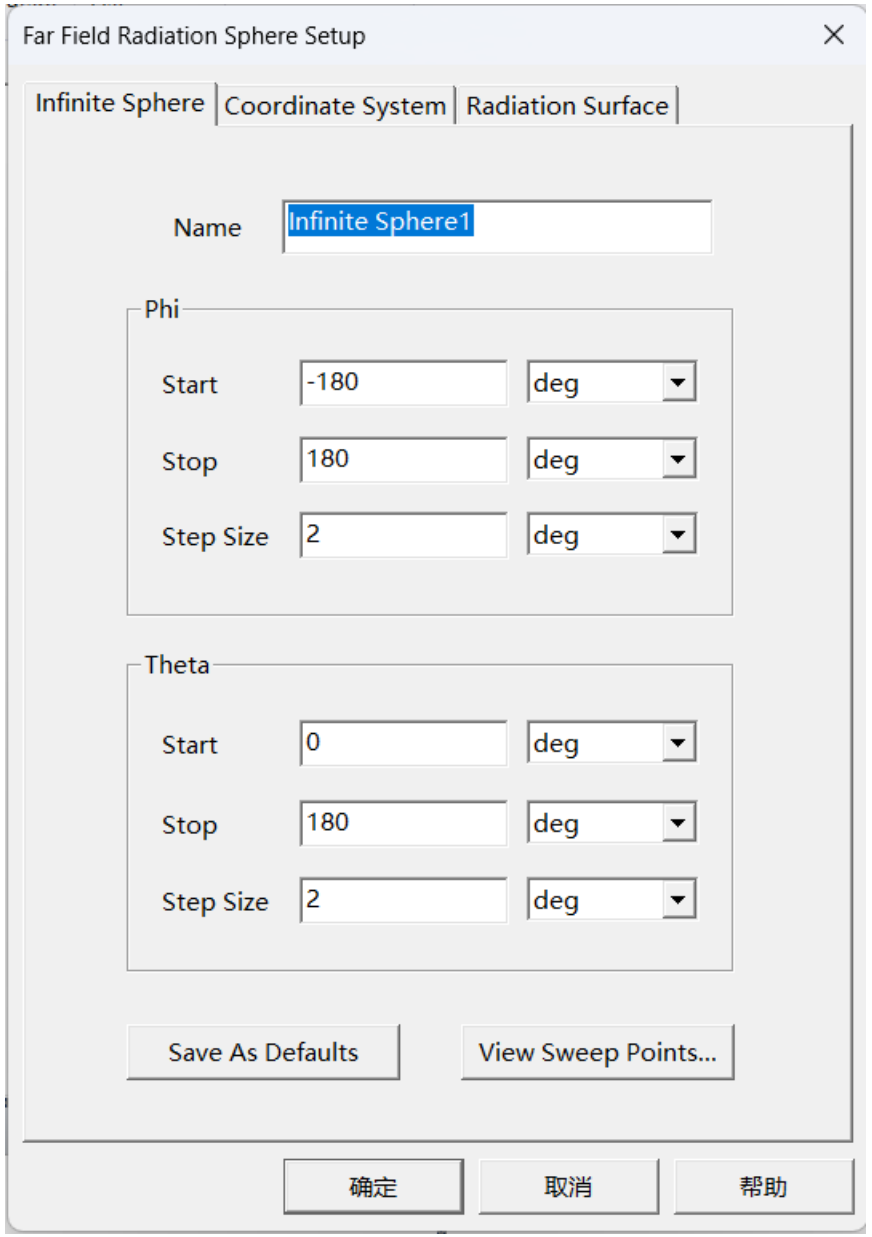
扫参结果


S Parameter Plot 2
HFSSDesign1
Curve Info
dB(S(1,1))
Setup1 : Sweep
L0='26mm'
dB(S(1,1))
Setup1 : Sweep
L0='26.5mm'
dB(S(1,1))
Setup1 : Sweep
L0='27mm'
dB(S(1,1))
Setup1 : Sweep
L0='27.5mm'
dB(S(1,1))
Setup1 : Sweep
L0='28mm'
dB(S(1,1))
Setup1 : Sweep
L0='28.5mm'
dB(S(1,1))
Setup1 : Sweep
L0='29mm'
2.33
2.37
2.41
2.45
2.49
2.53
2.56
2.59
2.63
2.39
2.43
2.47
2.51
2.55
-10.02
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
dB(S(1,1))
2.00
2.20
2.40
2.60
2.80
3.00
Freq [GHz]

远场方向图

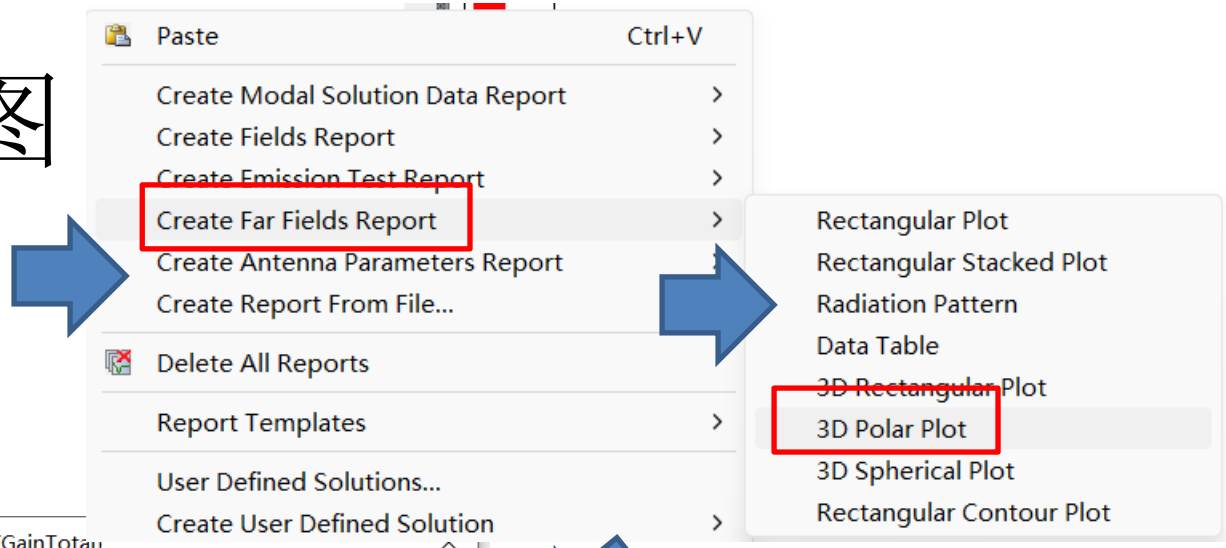
Right Click on Radiation

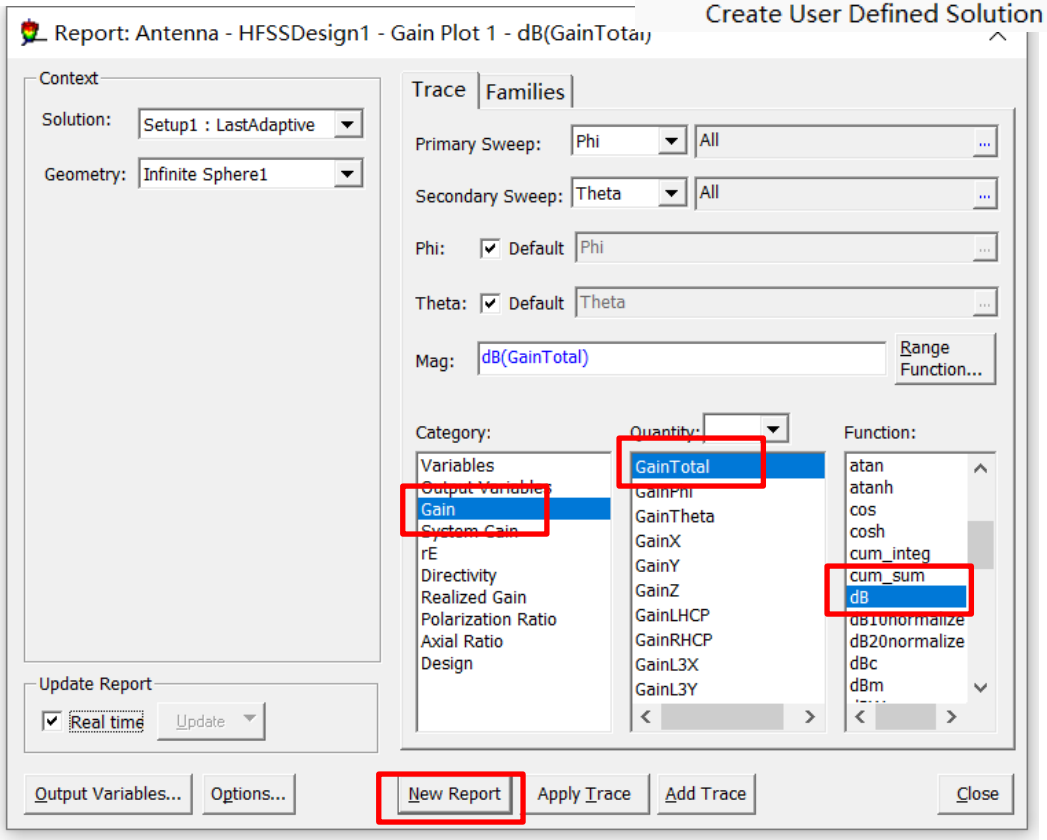


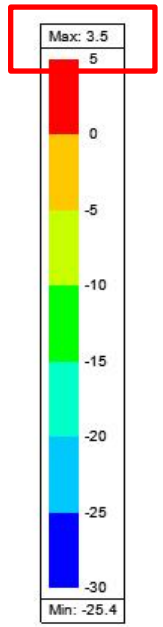


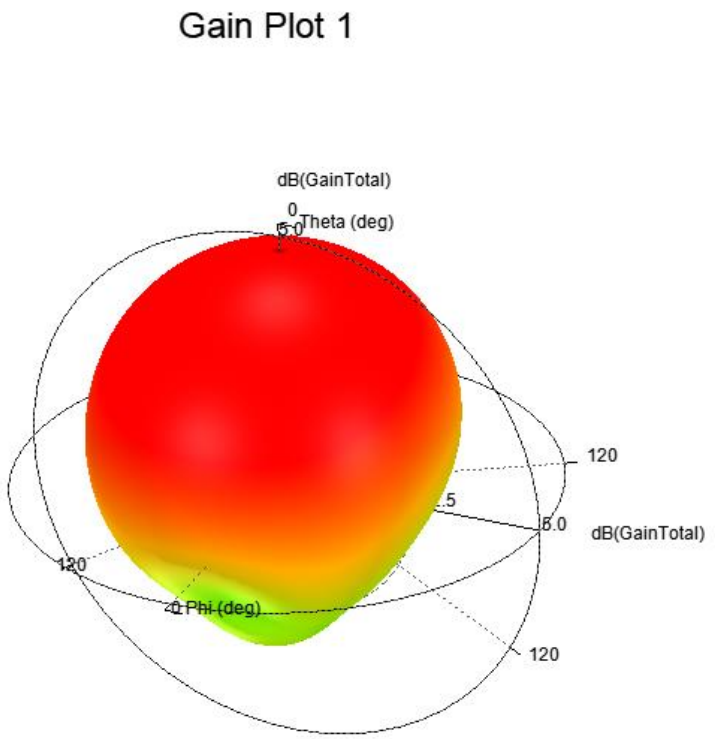
远场方向图

Right Click on Results









Homework

Center Frequency： 2.4 GHz

Substrate： FR4， 1.6mm

Bandwidth： 50MHz

Set W0 = 45mm， Observe GainTotal