Design and Simulation Microstrip patch Antenna using CST Microwave Studio

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Design and Simulation Microstrip patch Antenna using CST Microwave Studio

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OUTLINES

1. Introduction on microstrip patch antenna (MPA)
2. Design MPA theoretically
3. Introduction on CST MICROWAVE STUDIO
4. Simulation MPA using CST MICROWAVE STUDIO

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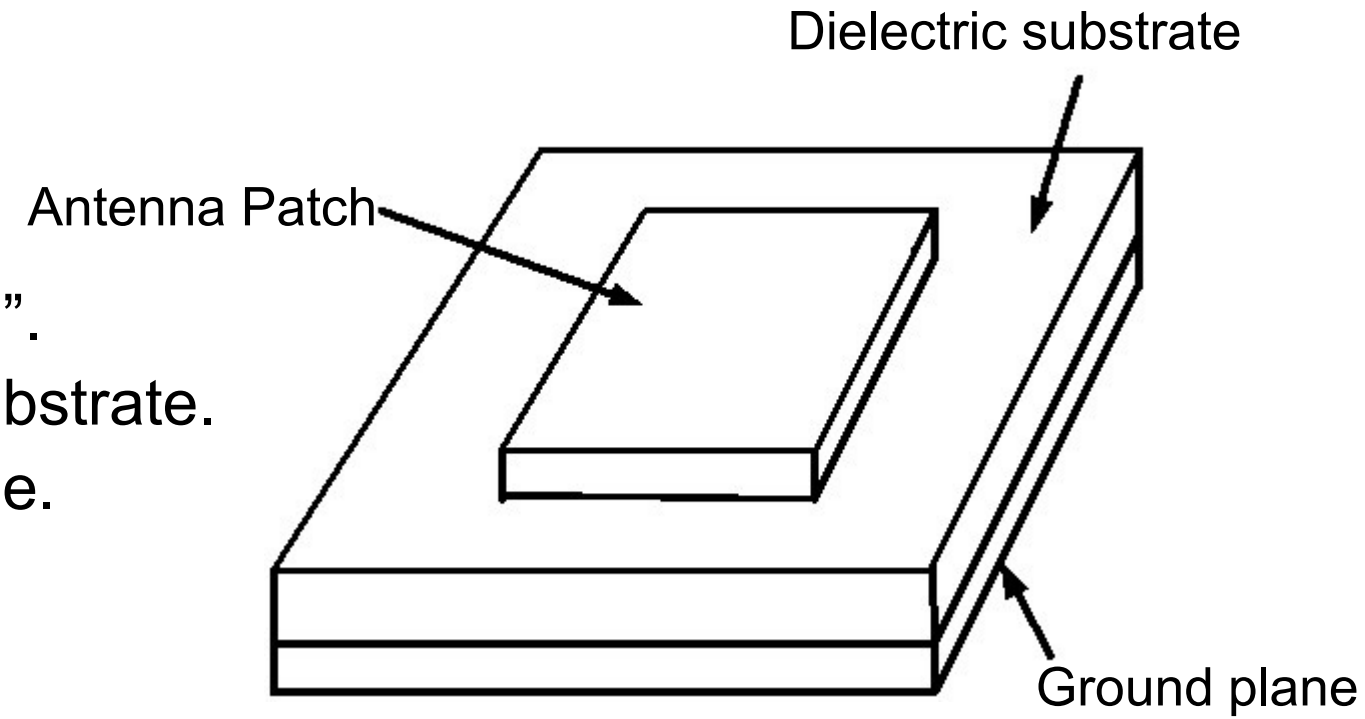
Introduction on Microstrip patch Antenna

- In general Microstrip patch antennas are also known as “PRINTED ANTENNAS ”.
- Operates on microwave frequencies (f > 1GHz).

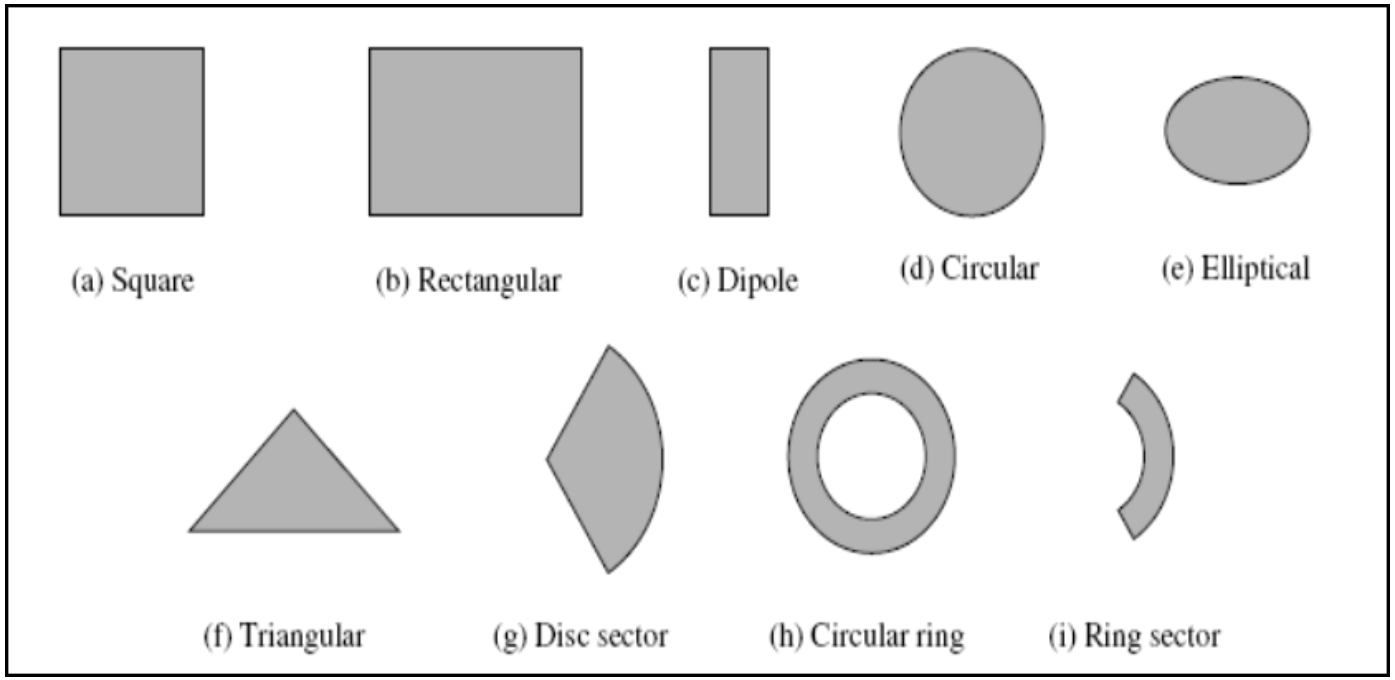
- Invented by Bob Munson in 1972.
- Became popular starting in the 1970s

Basically, the Microstrip Patch Antenna consists of :

- Metal “Patch”.
- Dielectric Substrate.
- Ground Plane.



- The patch can take different shapes , such as rectangular, circular, triangular, or U-shaped , E-shaped, etc.



Advantages of Microstrip Antennas:

- Easy to fabricate.
- Low cost , Less size.
- Can be integrated with microwave circuits.
- Easy to feed (coaxial cable, microstrip line, etc.) .
- Easy to use in an array.

Disadvantages of Microstrip Antennas

- Low gain.
- Low efficiency.
- Narrow bandwidth.

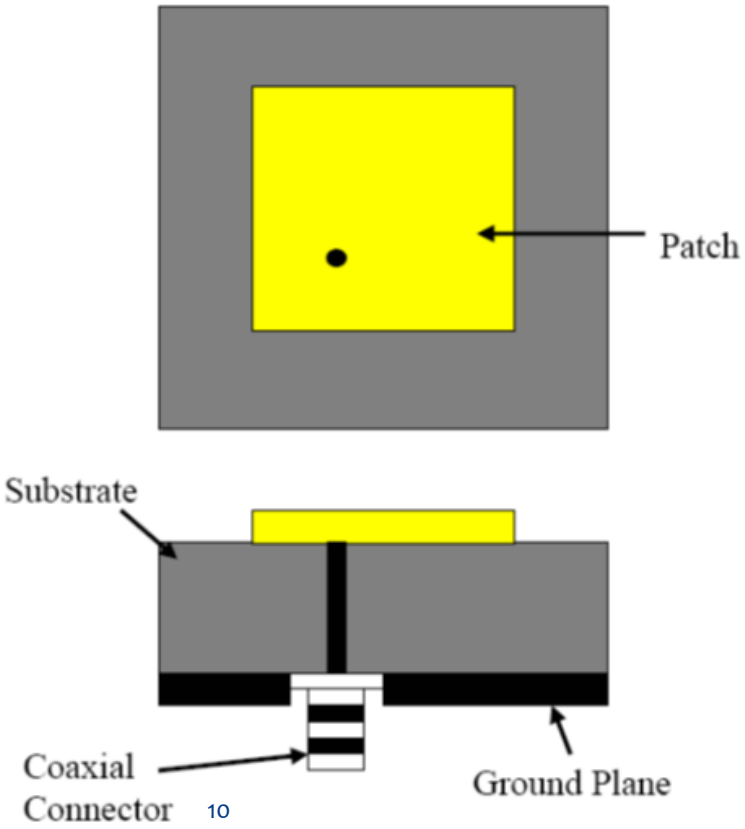
Applications

- in mobile satellite communication system.
- Wireless LAN'S.
- GPS system.
- Missiles ……. etc.

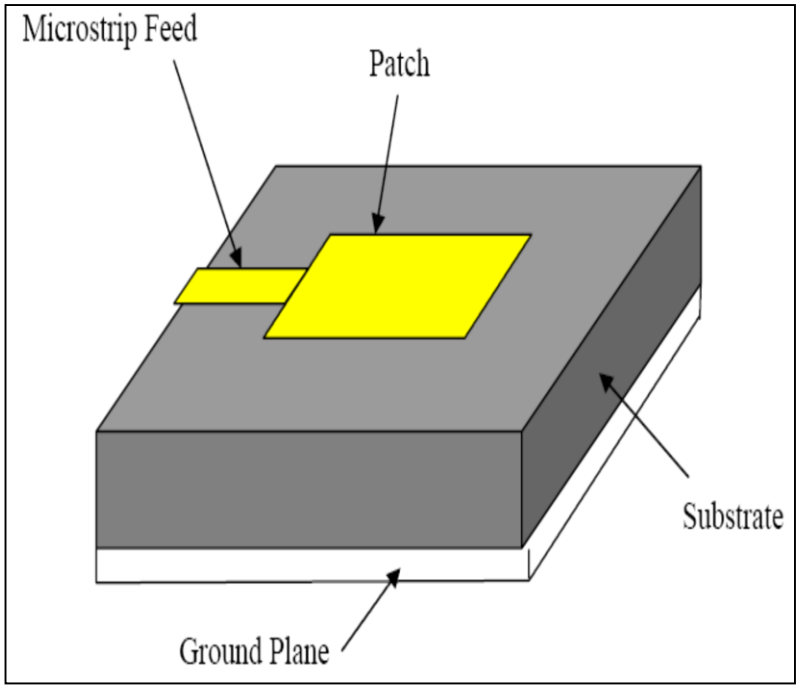
Feedings

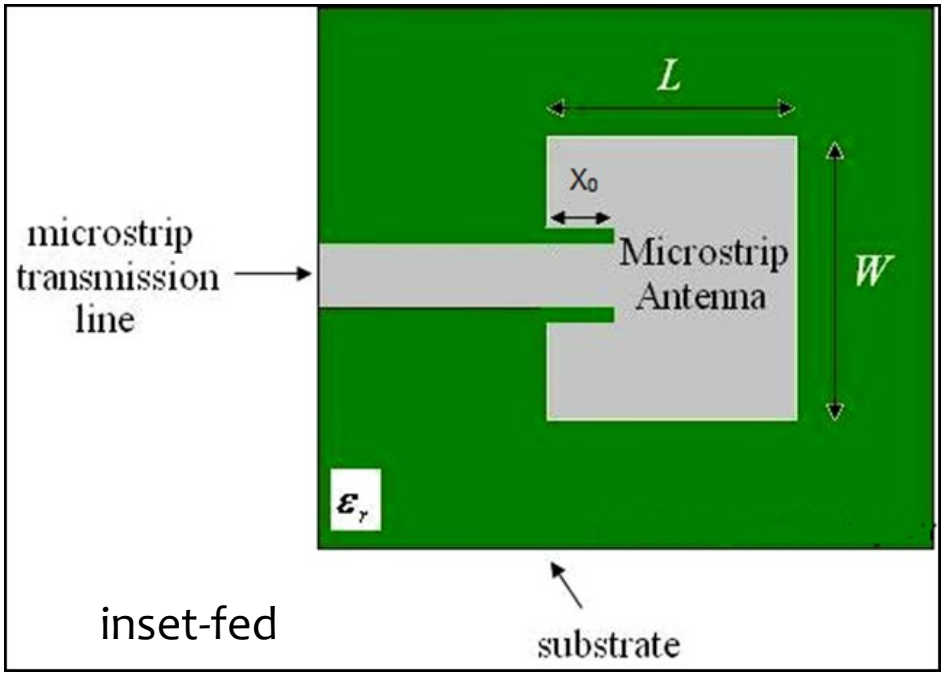
Microstrip patch antenna feeds with different mechanism feedings, the four most popular are :-

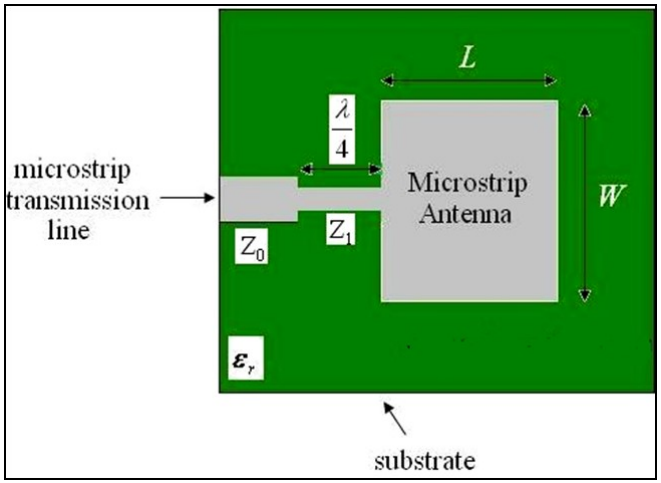
- Coaxial Cable



- Microstrip Line

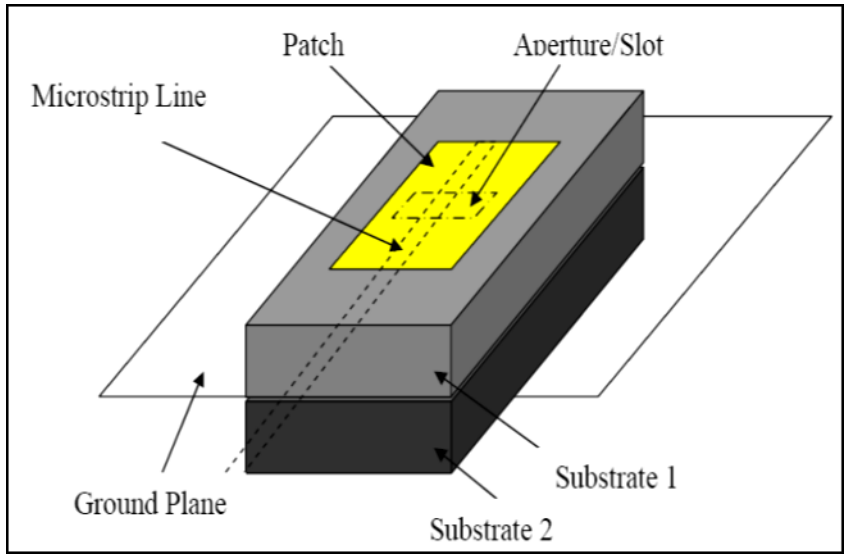


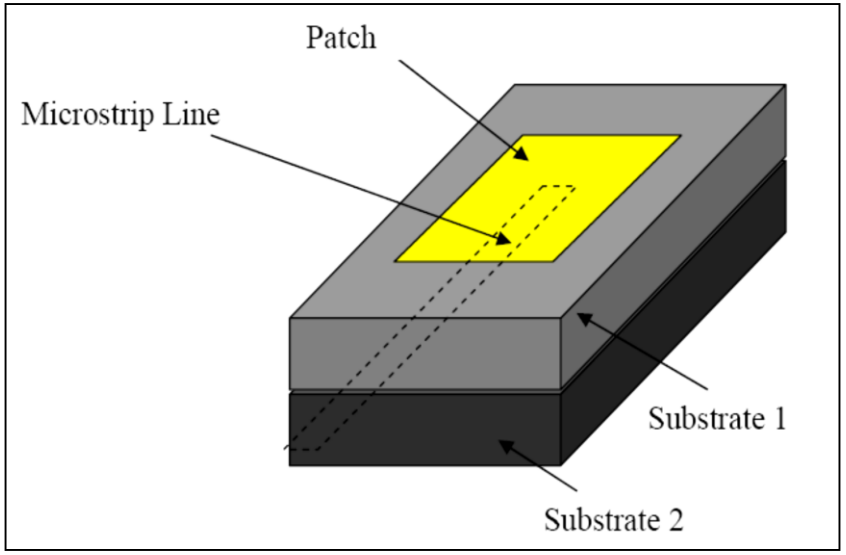




quarter-wavelength feed

- Aperture coupled (slot) Feed
- Proximity coupled Feed



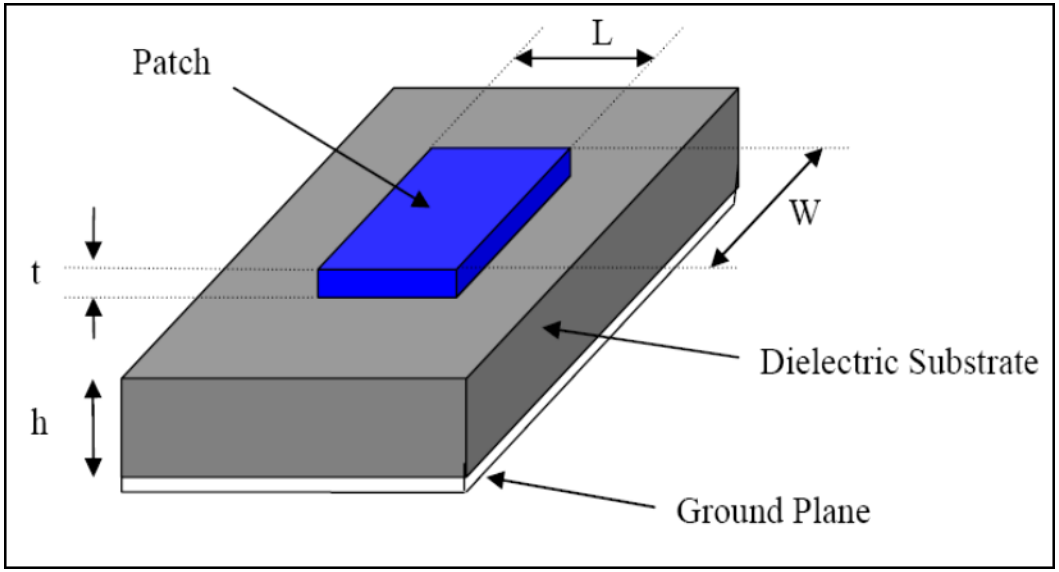


Design Rectangular Microstrip Patch Antenna With Microstrip Feed Line theoretically

To design a Rectangular patch antenna.

There are four essential parameters which are important to know:-

- The operating frequency (f_o).
- Dielectric constant of substrate (ε_r).
- The height of the dielectric substrate (h).
- The height of the conductor (t).



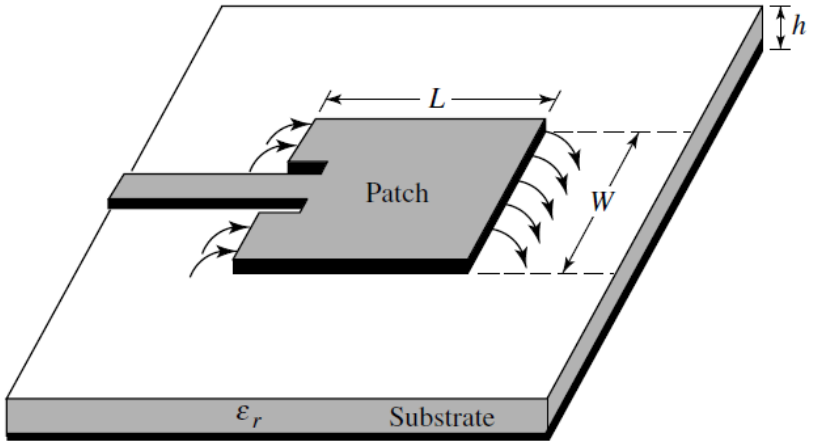
The other parameters:

- The width of the patch (W)
- The length of the patch (L)
- The width and length of the Ground plane and the substrate (Wg)(Lg).

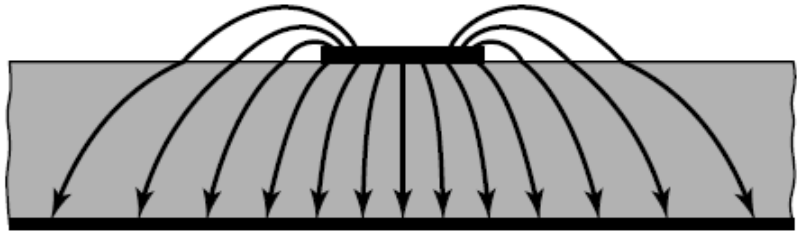
There are a a lot of methods for analysis microstrip patch antenna:

- The Transmission Line model.
- The Cavity model.
- Method of Moments (MoM).

The Transmission Line model is the easiest of all



(a) Microstrip line feed



(b) Electric field lines

The Transmission Line equations

- To Find Width (W) $W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon r+1)}{2}}}$

- To find the effective dielectric constant

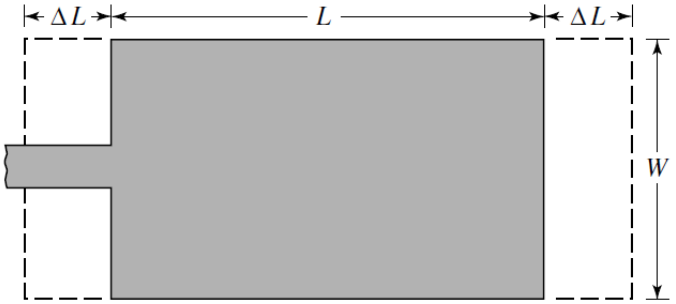
$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1 + 12\,\frac{h}{W}\right)^{-1/2}$$

- To find the effective length

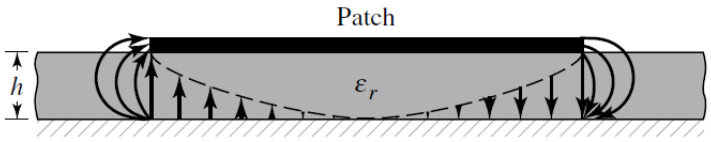
$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon reff}}$$

- To find the fringing length (ΔL)

$$\Delta L = 0.412\,h\,\frac{(\varepsilon reff+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon reff-0.258)\left(\frac{W}{h}-0.8\right)}$$



(a) Top view



(b) Side view

4.7 Physical and effective lengths of rectangular microstrip patch

- To find the actual length L and the width and length of the Ground

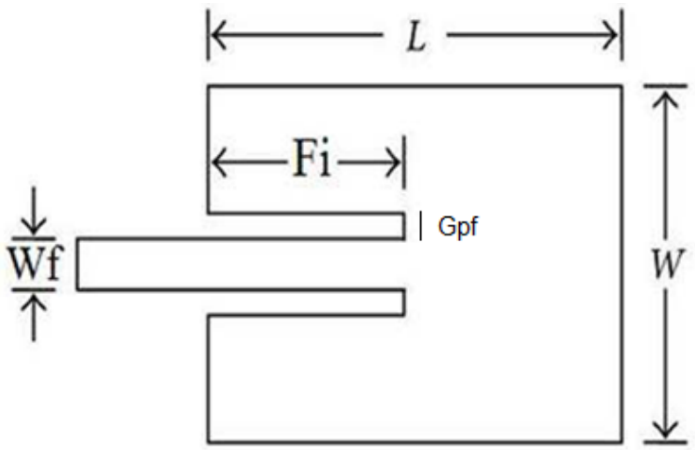
$$L = L_{eff} - 2\Delta L \qquad L_g = 2 * L \qquad W_g = 2 * W$$

To design the microstrip feed line (inset-fed)

- The input impedance is usually 50 Ω.
- The width of Microstrip feed line (Wf).

$$Z_c = \begin{cases} \dfrac{60}{\sqrt{\epsilon_{reff}}} \ln\left[\dfrac{8h}{W_0} + \dfrac{W_0}{4h}\right], & \dfrac{W_0}{h} \le 1 \\ \dfrac{120\pi}{\sqrt{\epsilon_{reff}}\left[\dfrac{W_0}{h} + 1.393 + 0.667 \ln\left(\dfrac{W_0}{h} + 1.444\right)\right]}, & \dfrac{W_0}{h} > 1 \end{cases}$$

where W_0 is the width of the microstrip line, as shown in Figure 14.11.



- The length of inset (Fi)

$$\text{fi} = 10^{-4}(0.001699 * \varepsilon_r^{7} + 0.13761 * \varepsilon_r^{6} - 6.1783 * \varepsilon_r^{5} + 93.187 * \varepsilon_r^{4} - 682.69 * \varepsilon_r^{3} + 2561.9 * \varepsilon_r^{2} - 4043 * \varepsilon_r + 6697) * \frac{L}{2}$$

- the gap between the patch and the inset-fed (Gpf) usualy 1 mm.

Example:-

To design a microstrip patch antenna with the microstrip feed line (inset-fed) for WiFi 2.4 GHz.

- The operating frequency (f_o) = 2.4 GHz.

FR4 material have:-

- Dielectric constant of substrate (ε_r) = 4.3.
- The height of the dielectric substrate (h) = 1.6 mm.
- The height of the conductor (t) = 0.035 mm.

To calculate the W, L of the patch by using the equations:-

$$W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon r+1)}{2}}}$$

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1 + 12\,\frac{h}{W}\right)^{-1/2}$$

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon reff}}$$

$$L_g = 2 * L$$

$$W_g = 2 * W$$

$$\Delta L = 0.412\,h\,\frac{(\varepsilon reff+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon reff-0.258)\left(\frac{W}{h}-0.8\right)}$$

$$L = L_{eff} - 2\Delta L$$

fi

$$= 10^{-4}(0.001699 * \varepsilon_r^{\,7} + 0.13761 * \varepsilon_r^{\,6} - 6.1783 * \varepsilon_r^{\,5} + 93.187 * \varepsilon_r^{\,4} - 682.69 * \varepsilon_r^{\,3} + 2561.9 * \varepsilon_r^{\,2} - 4043 * \varepsilon_r + 6697) * \frac{L}{2}$$

- *C = 299792458 or 3* 10^8 m/se*
- f_o = 2.4 GHz or 2.4*10^9 Hz
- FR4 ► εr = 4.3, h=1.6 mm, t= 0.035 mm
- W≈ 38 mm, L≈ 29 mm , Fi≈8.85 mm

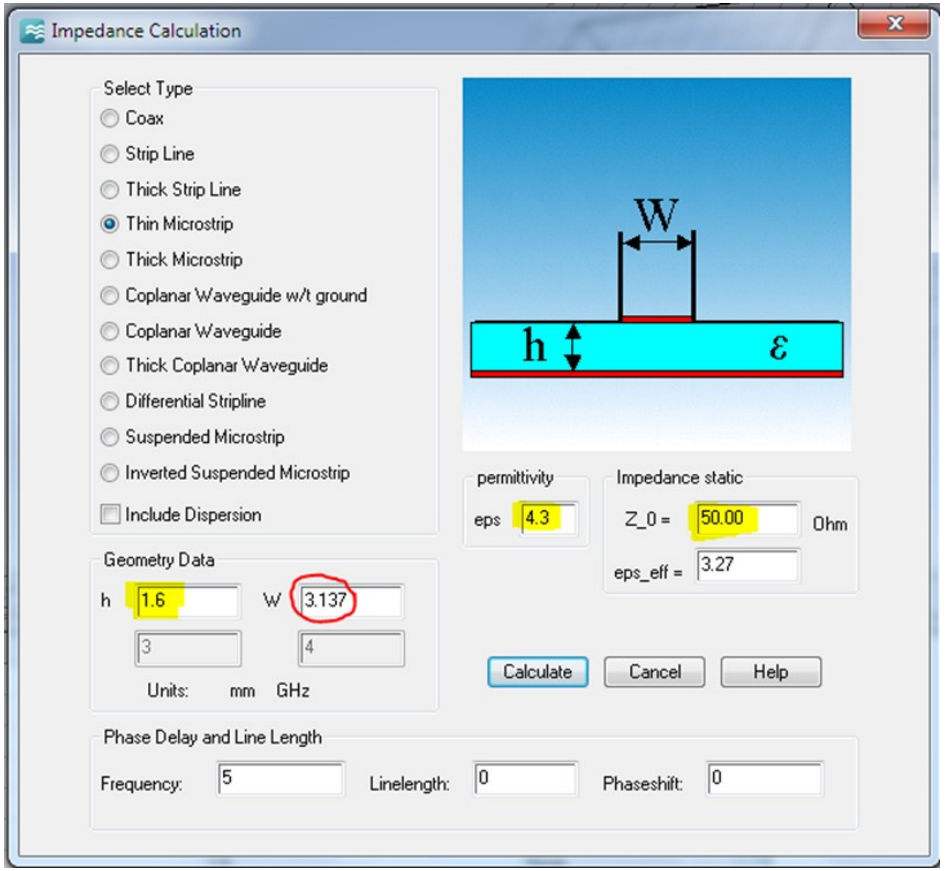
To calculate
The feed line width Wf

$$Z_c = \begin{cases} \dfrac{60}{\sqrt{\epsilon_{reff}}} \ln\left[\dfrac{8h}{W_0} + \dfrac{W_0}{4h}\right], & \dfrac{W_0}{h} \le 1 \\ \dfrac{120\pi}{\sqrt{\epsilon_{reff}}\left[\dfrac{W_0}{h} + 1.393 + 0.667 \ln\left(\dfrac{W_0}{h} + 1.444\right)\right]}, & \dfrac{W_0}{h} > 1 \end{cases}$$

where W_0 is the width of the microstrip line, as shown in Figure 14.11.

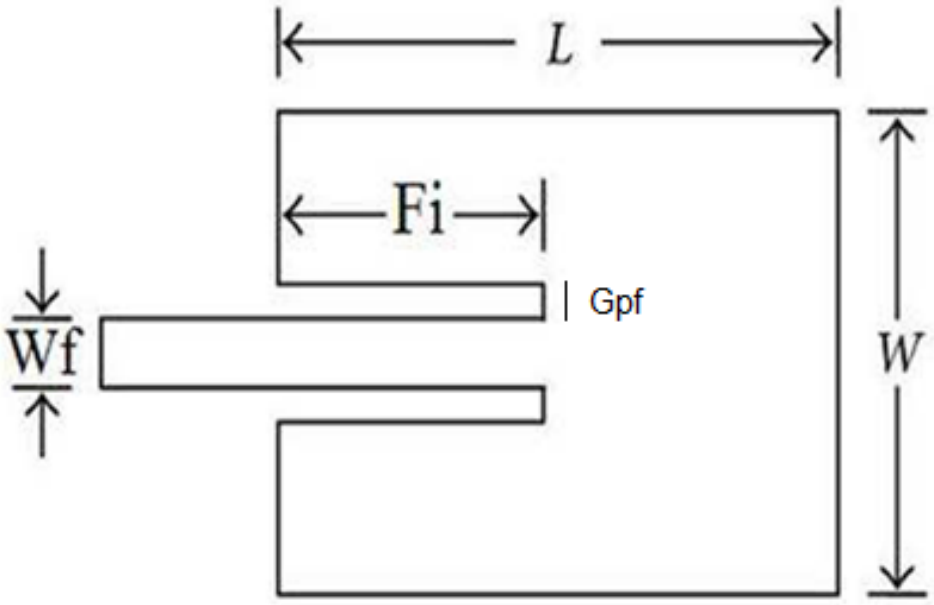
Or using transmission line software or CST

- Wf≈3.137 mm



The Parameters

Parameters	mm
W	38
L	29
Fi	8.85
Wf	3.137
Gpf	1
Lg	2*L
Wg	2*W
ht	0.035
hs	1.6



Introduction about CST

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CST
Computer Simulation Technology

https://www.cst.com/

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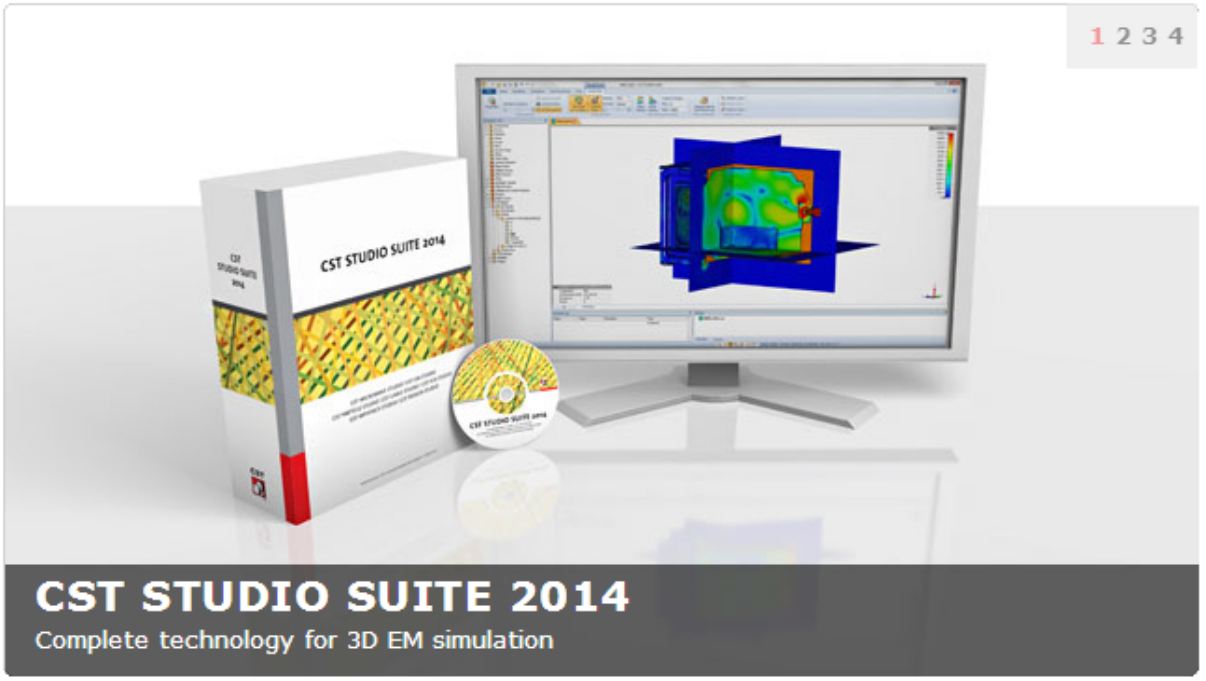
3D ELECTROMAGNETIC SIMULATION SOFTWARE

CST offers accurate, efficient computational solutions for **electromagnetic design** and analysis. Our user-friendly 3D **EM simulation software** enables you to choose the most appropriate method for the design and optimization of devices operating in a wide range of frequencies.

REQUEST EVALUATION



 CST MICROWAVE STUDIO®	**CST MICROWAVE STUDIO®** is a specialized tool for the fast and accurate 3D EM simulation of high frequency problems. Along with a broad application range, it offers considerable product-to-market advantages: shorter development cycles; virtual prototyping before physical trials; optimization instead of experimentation.
 CST EM STUDIO®	**CST EM STUDIO®** is an easy-to-use tool for the analysis and design of static and low frequency structures. Applications include: actuators, brakes, EMC, generators, measurement, motors, sensors and shielding.
 CST PARTICLE STUDIO®	**CST PARTICLE STUDIO®** is a specialized tool for the fast and accurate design and analysis of 3D electron guns. This new software is based on the multi-purpose electromagnetic solvers of the CST STUDIO family and incorporates their powerful modelling capabilities in addition to successful algorithms of the MAFIA-TS simulators.
 CST MPHYSICS STUDIO™	**CST MPHYSICS STUDIO™** is a tool to analyze thermal and structural mechanics problems.
 CST DESIG STUDIO™	**CST DESIGN STUDIO™** represents a universal platform to manage the entire design process of a complex system beginning with a first layout and closing with the final solution. By constructing elementary sub-systems, the user can analyze the behavior of the complete system in small segments.
 CST PCB STUDIO™	**CST PCB STUDIO™** is a tool for the investigation of Signal and Power Integrity and the simulation of EMC and EMI effects on Printed Circuit Boards (PCB).
 CST CABLE STUDIO™	**CST CABLE STUDIO™** is a tool for the analysis of SI, EMC and EMI effects in cable systems including single wires, twisted pairs as well as complex cable harnesses.
 CST MICROSTRIPES™	**CST MICROSTRIPES™** is a powerful 3D electromagnetic simulation tool, used extensively for solving challenging radiation problems including complex antenna structures, installed performance, EMC/EMI/E3 issues.

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Simulation Microstrip Patch Antenna using CST MICROWAVE STUDIO

CST MICROWAVE STUDIO

2014

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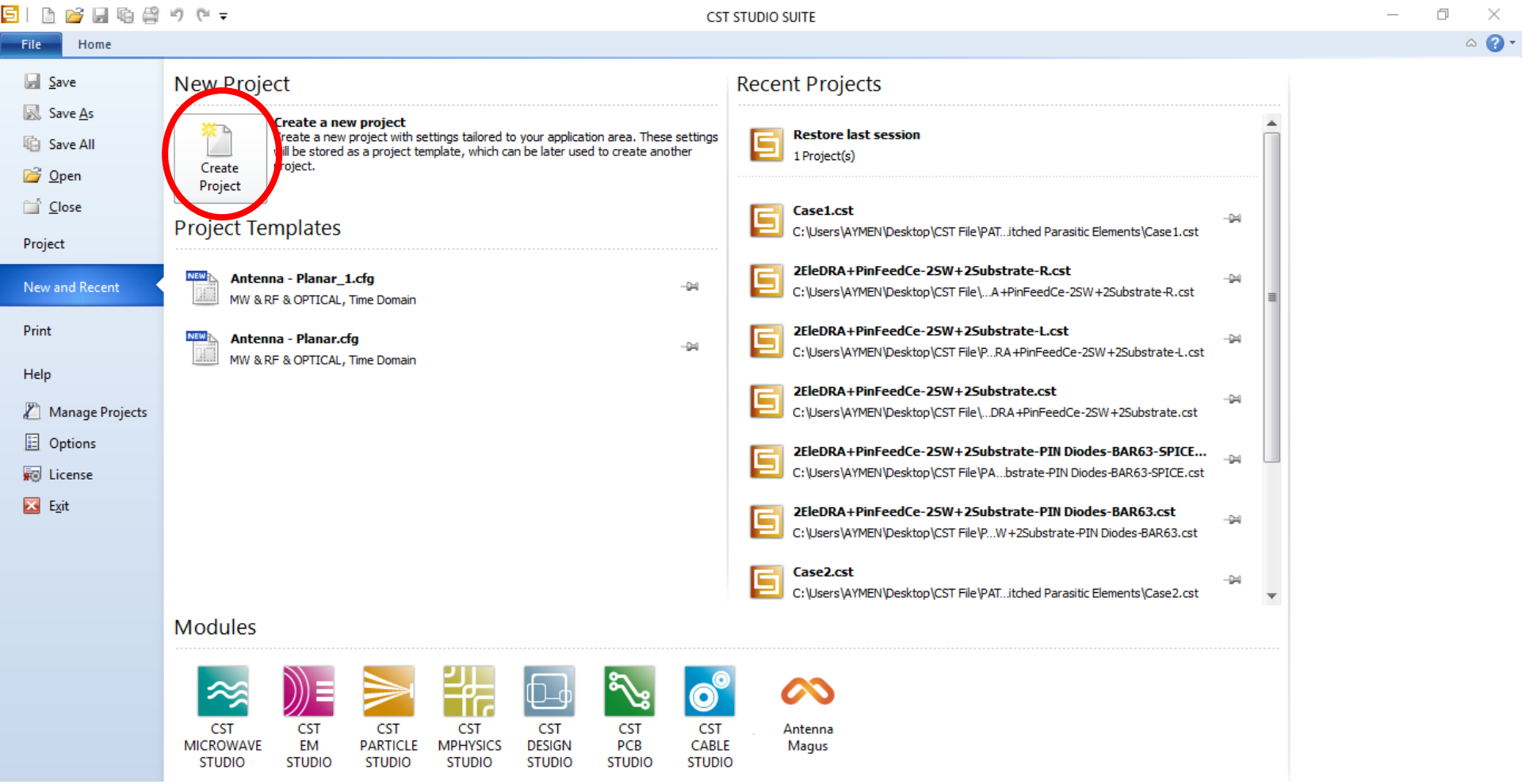
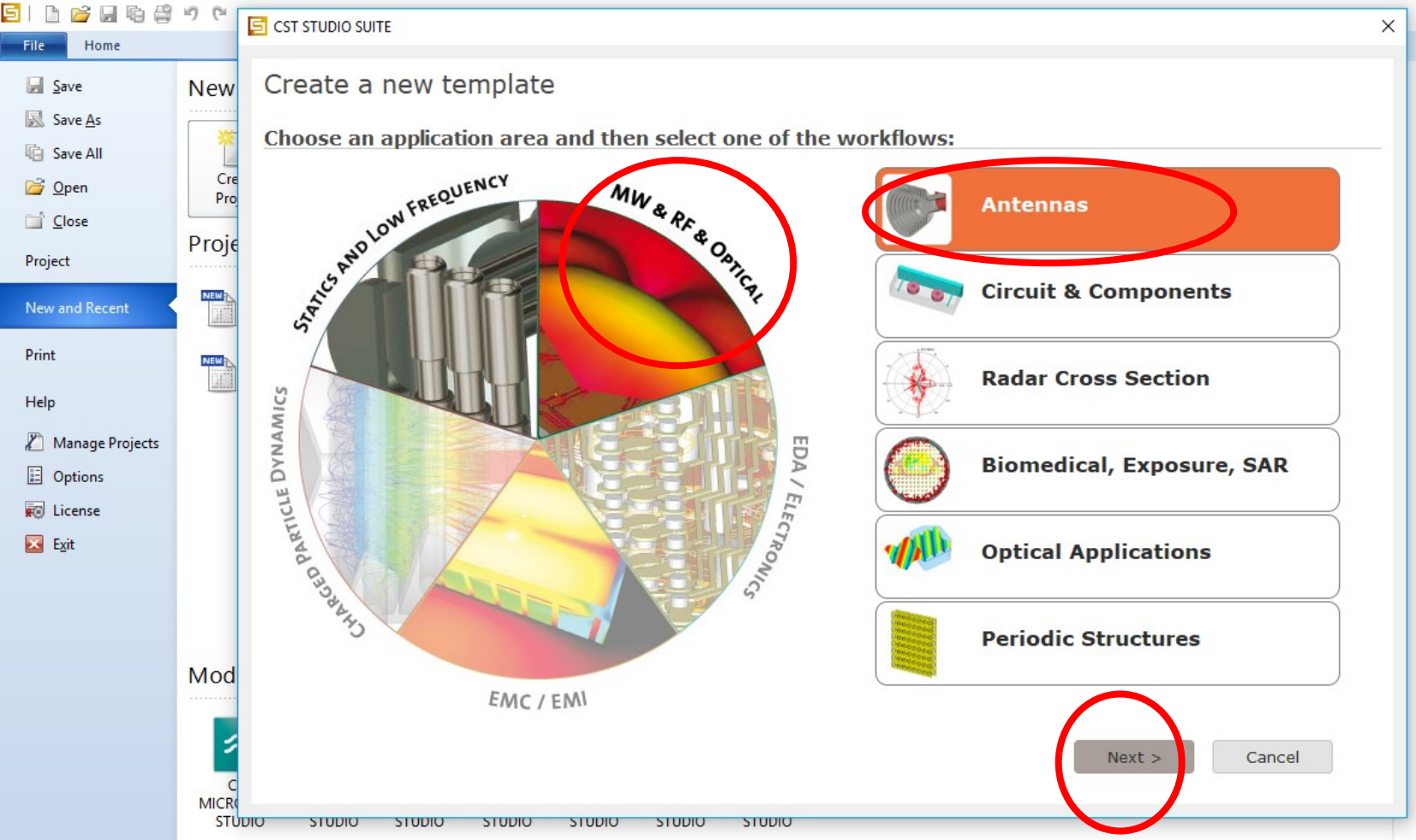
1-Create project

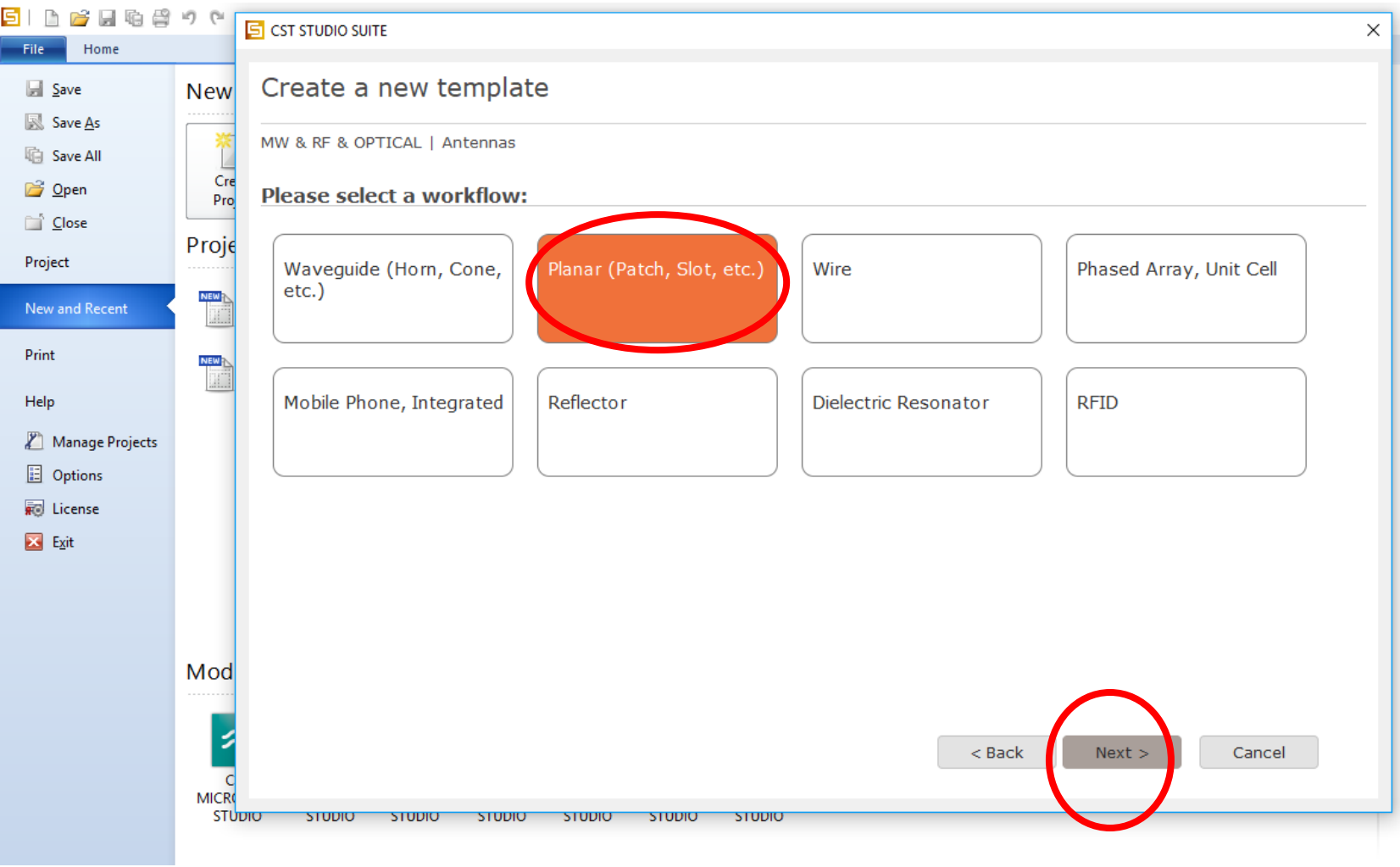


2- Choose MW & RF & optical

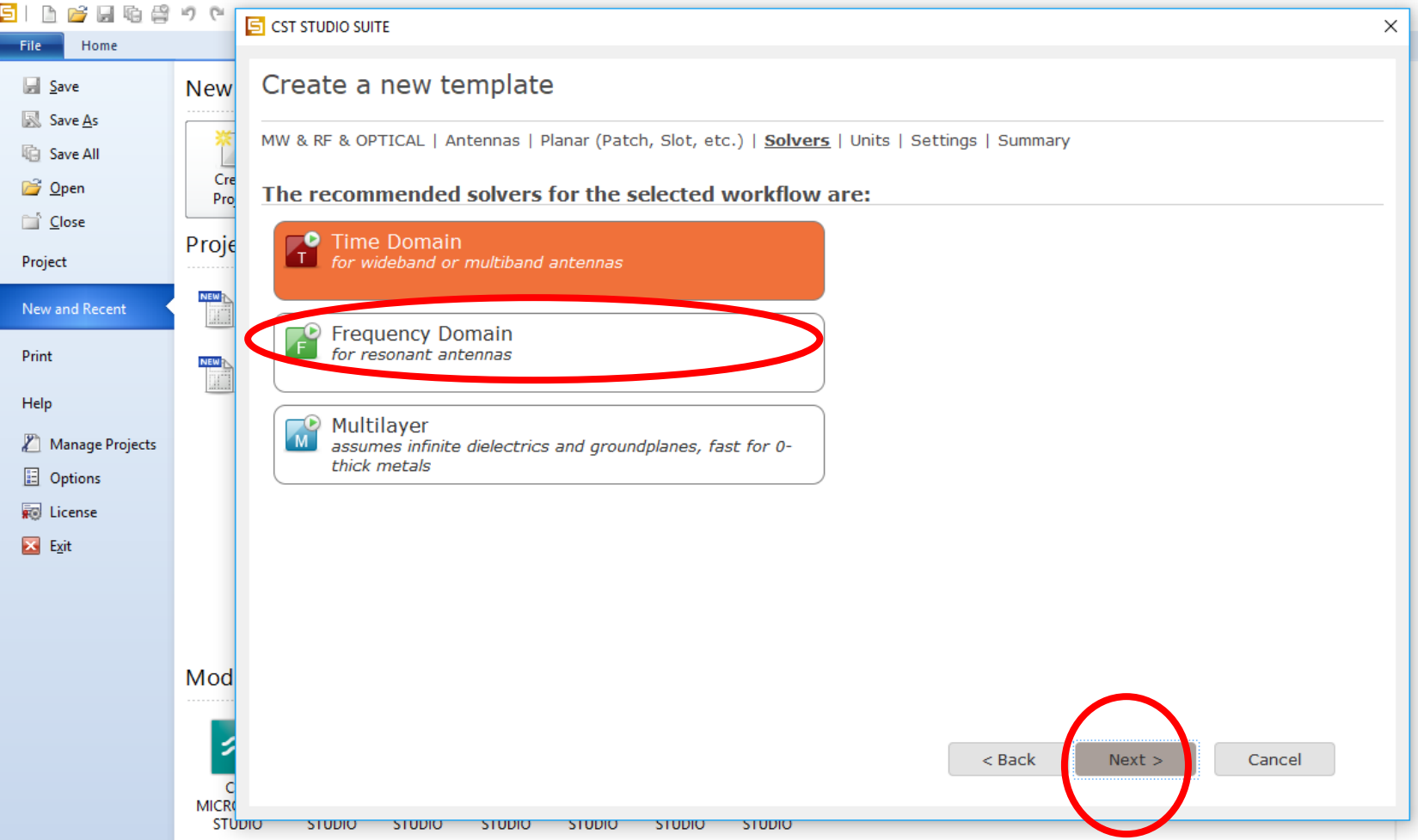
3- Choose Antennas



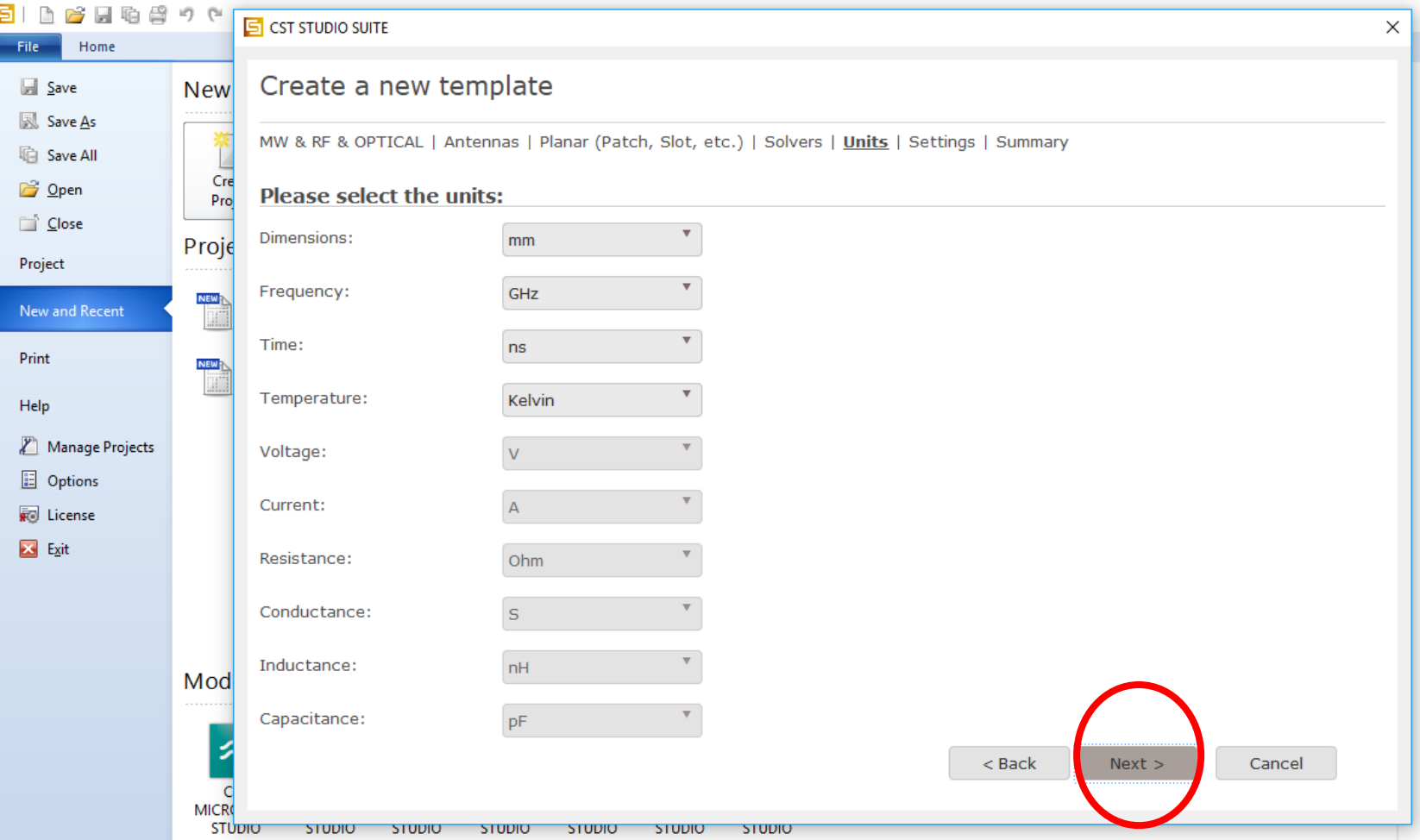
4- Select Planar (patch, Slot, etc.)



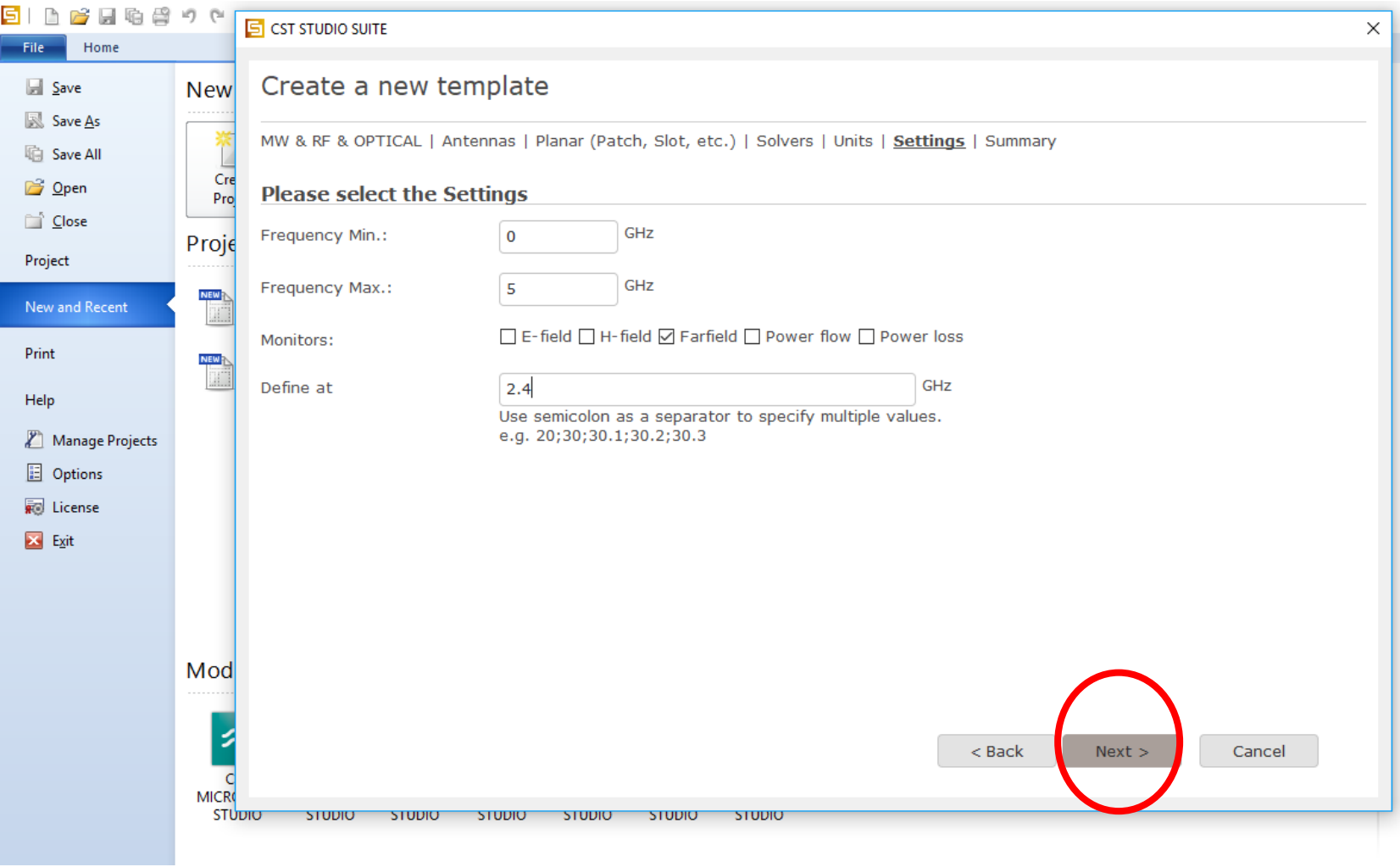
5- Choose Time Domain



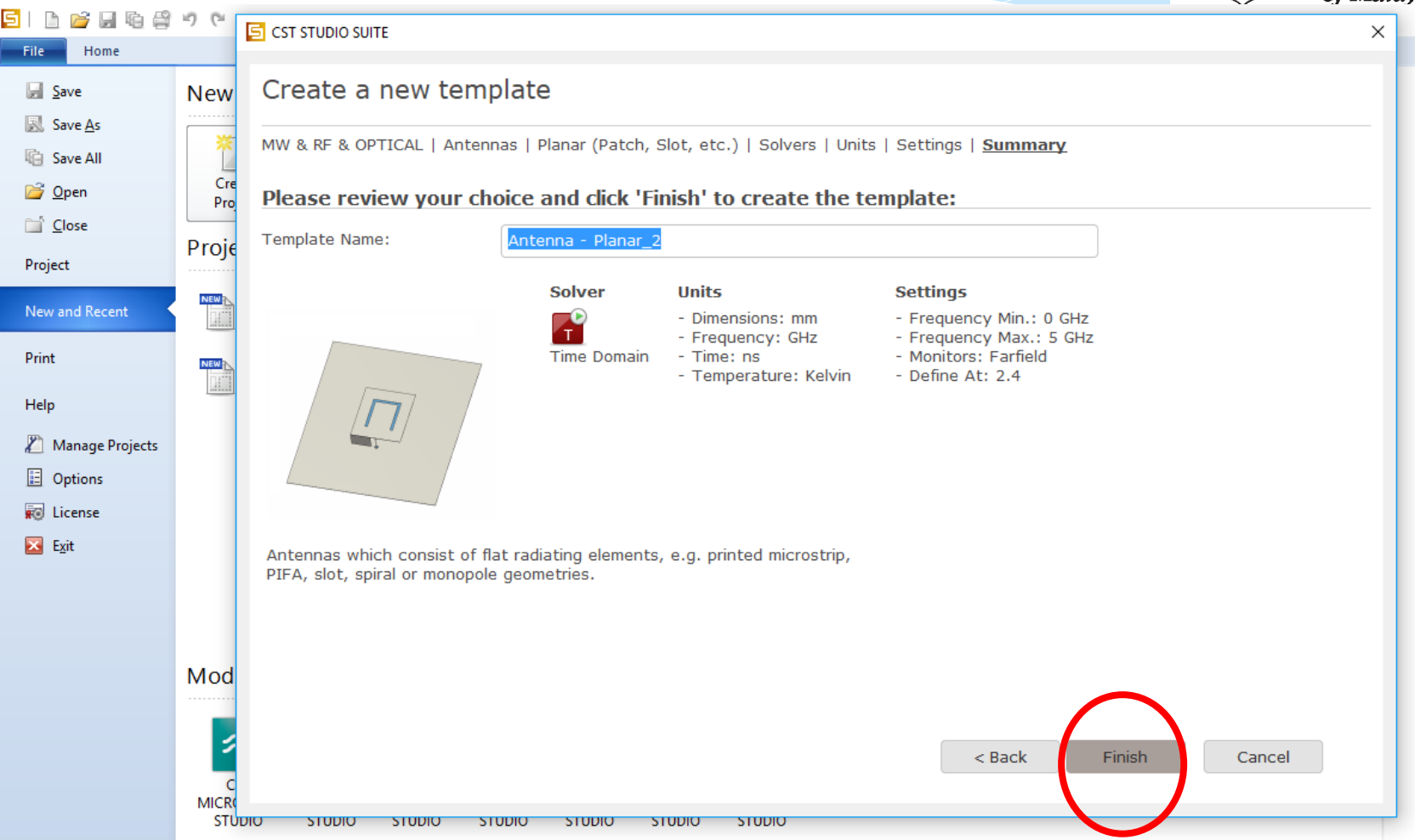
6- Select the units



7- Select the frequency range and monitors farfield at resonant frequency or any frequency need to monitor



8- Finish


File
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Save As
Save All
Open
Close
Project
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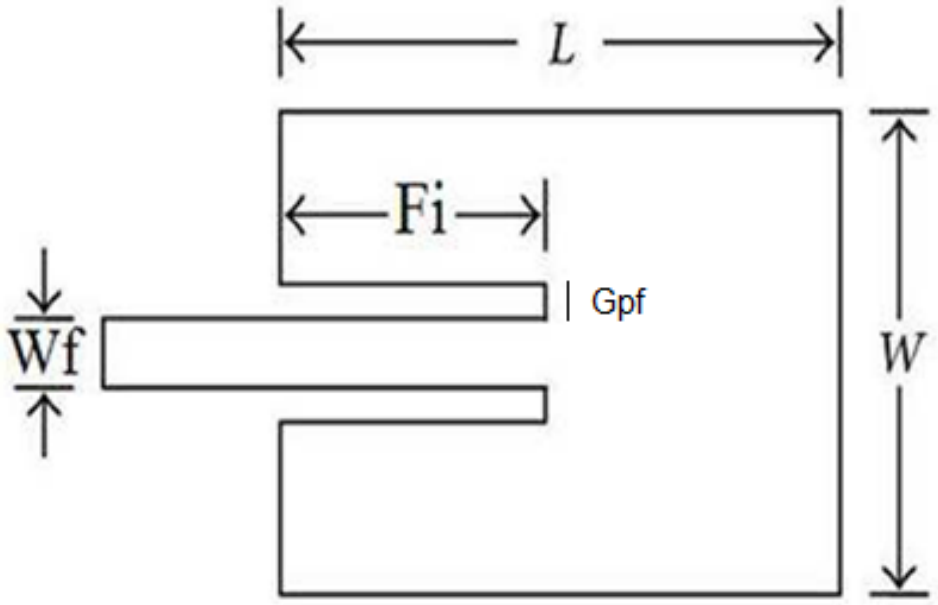
Print
Help
Manage Projects
Options
License
Exit
New
Proje
Mod
CST STUDIO SUITE
Create a new template
MW & RF & OPTICAL | Antennas | Planar (Patch, Slot, etc.) | Solvers | Units | Settings | Summary
Please review your choice and click 'Finish' to create the template:
Template Name:
Antenna - Planar_2
Solver
Time Domain
Units
- Dimensions: mm
- Frequency: GHz
- Time: ns
- Temperature: Kelvin
Settings
- Frequency Min.: 0 GHz
- Frequency Max.: 5 GHz
- Monitors: Farfield
- Define At: 2.4
Antennas which consist of flat radiating elements, e.g. printed microstrip, PIFA, slot, spiral or monopole geometries.
< Back
Finish
Cancel

The Parameters

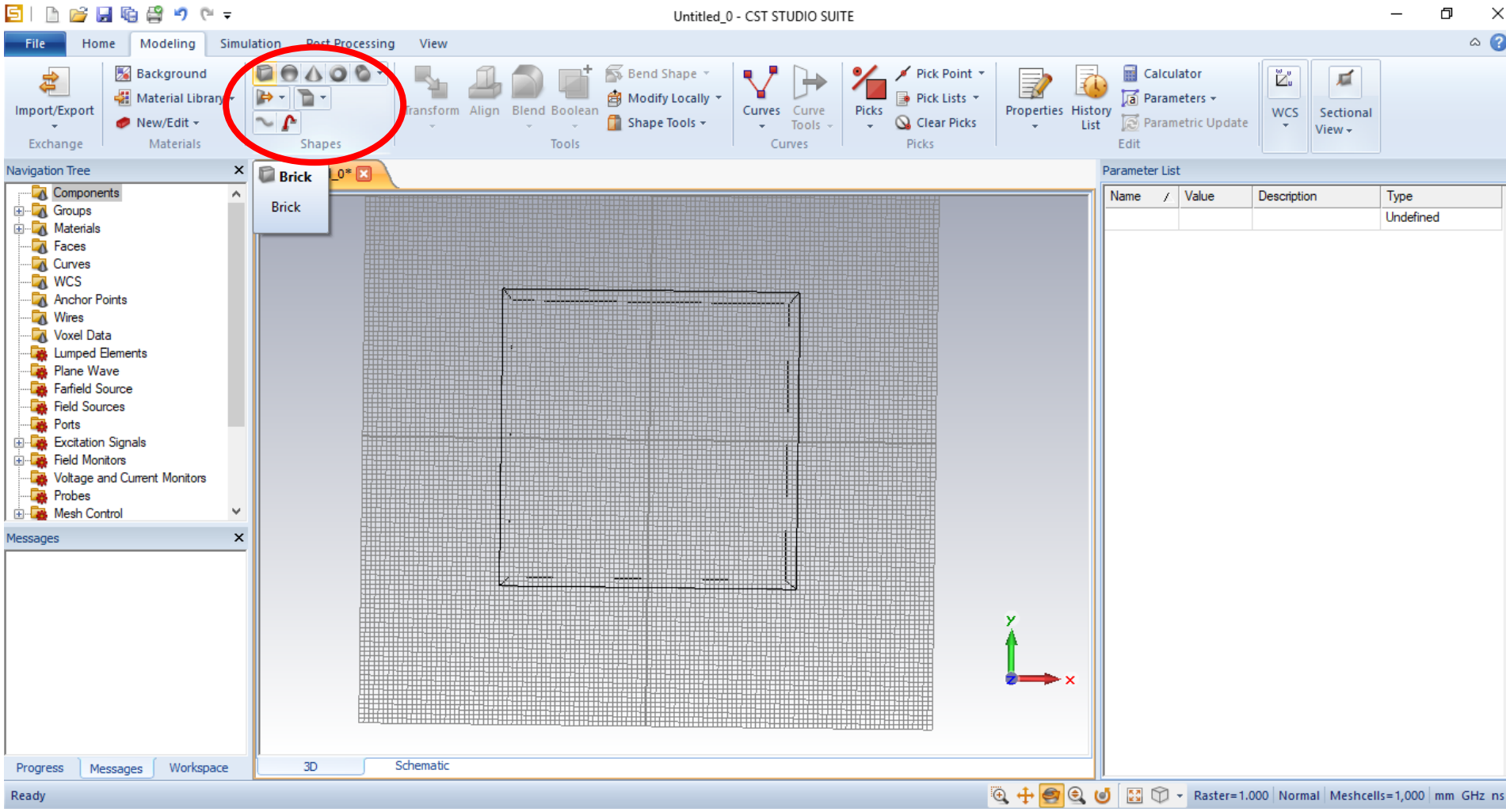
For design a microstrip patch antenna with the microstrip feed line (inset-fed) work on 2.4 GHz for WiFi.

Parameters	mm
W	38
L	29
Fi	8.85
Wf	3.137
Gpf	1
Lg	2*L
Wg	2*W
ht	0.035
hs	1.6

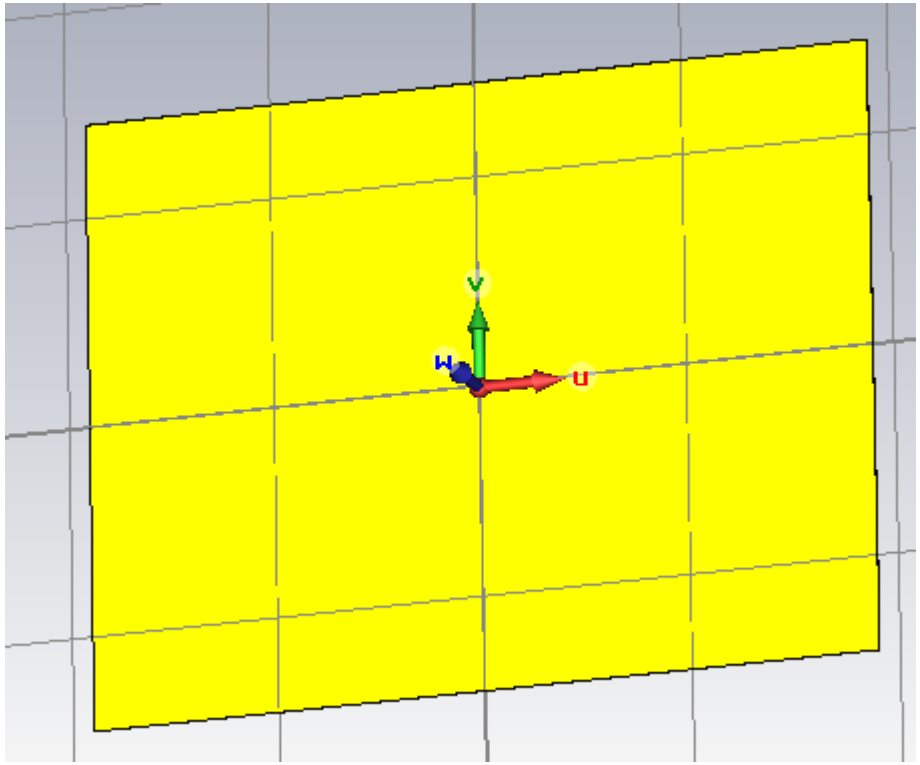


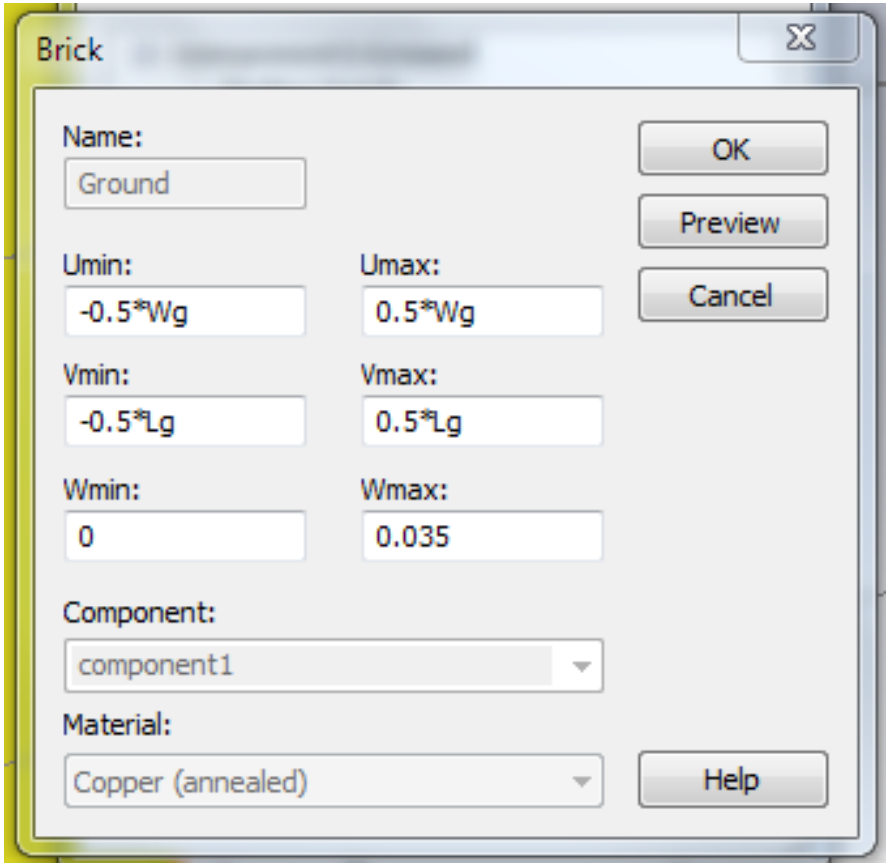
The frequency range between 1.8 to 3

- Modeling → shapes click create brick then press Esc from the keyboard

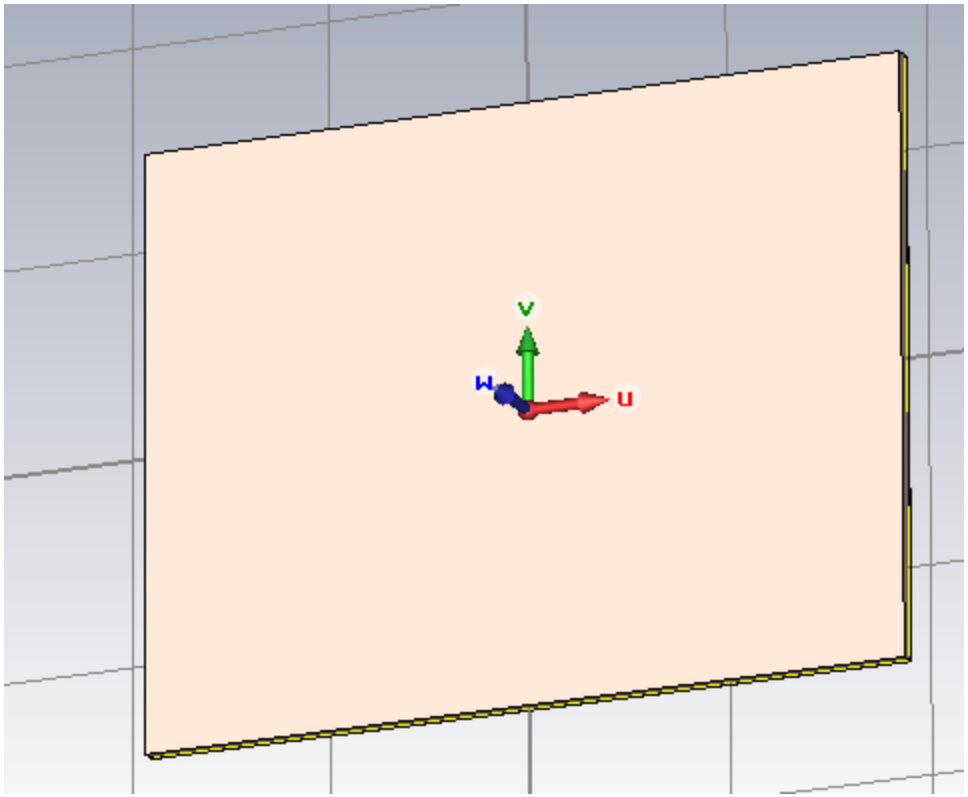


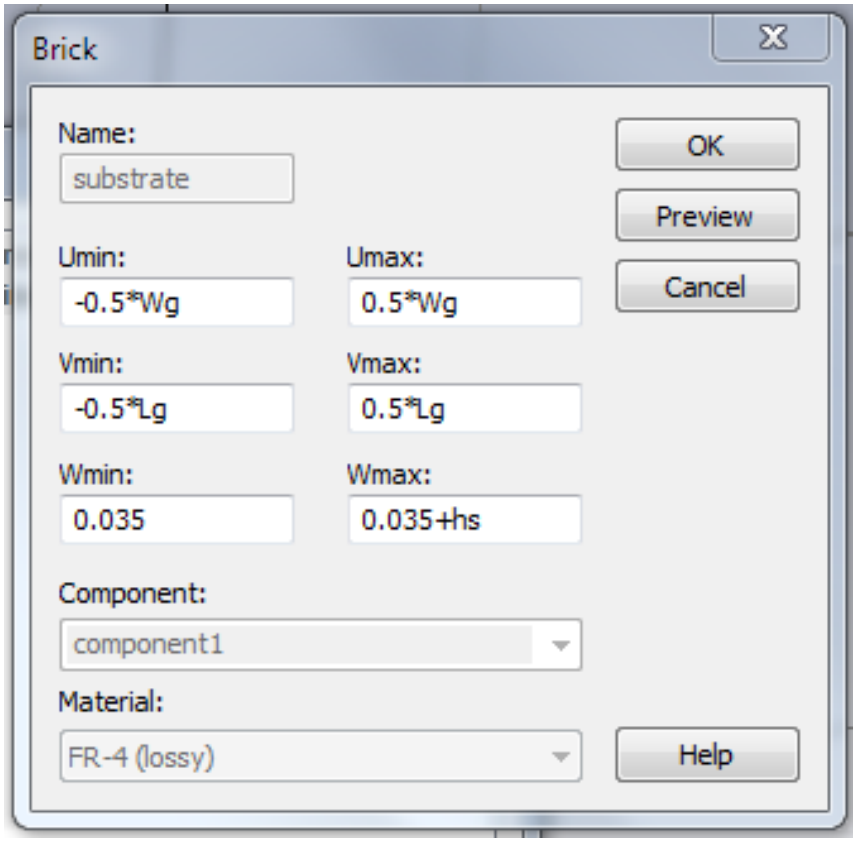
- Create ground plane



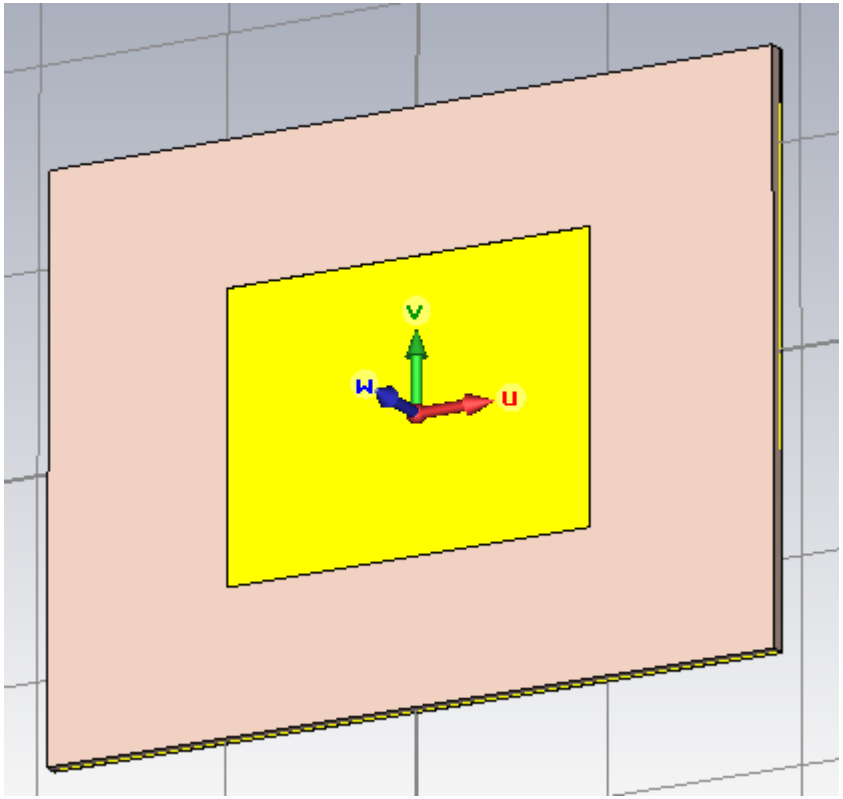


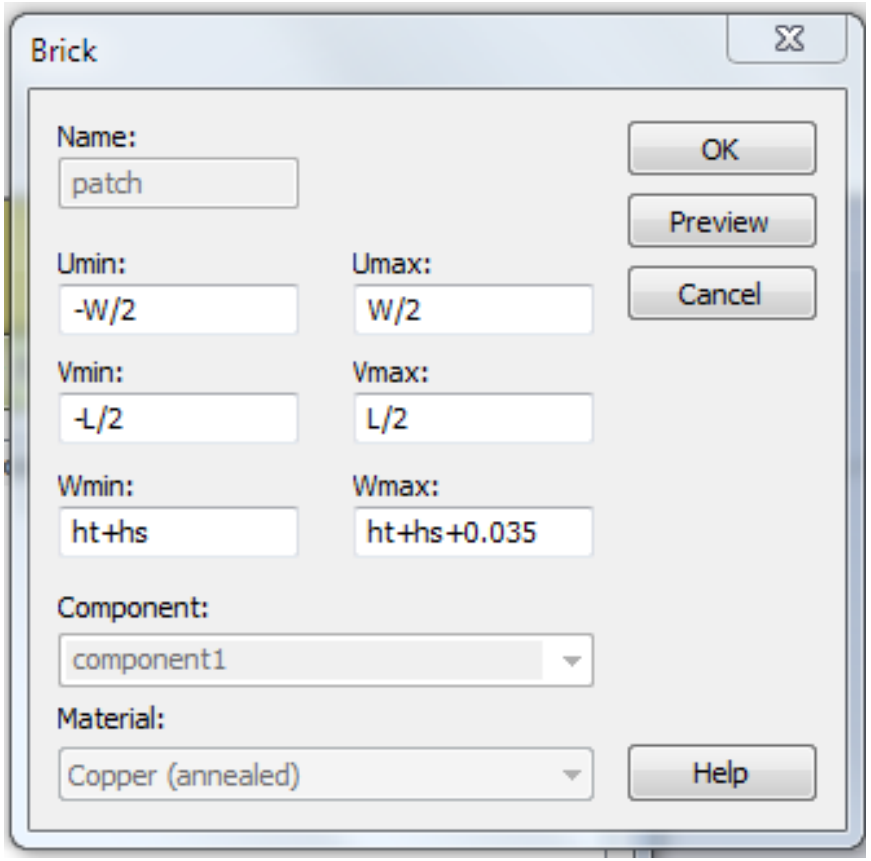
- Create the substrate



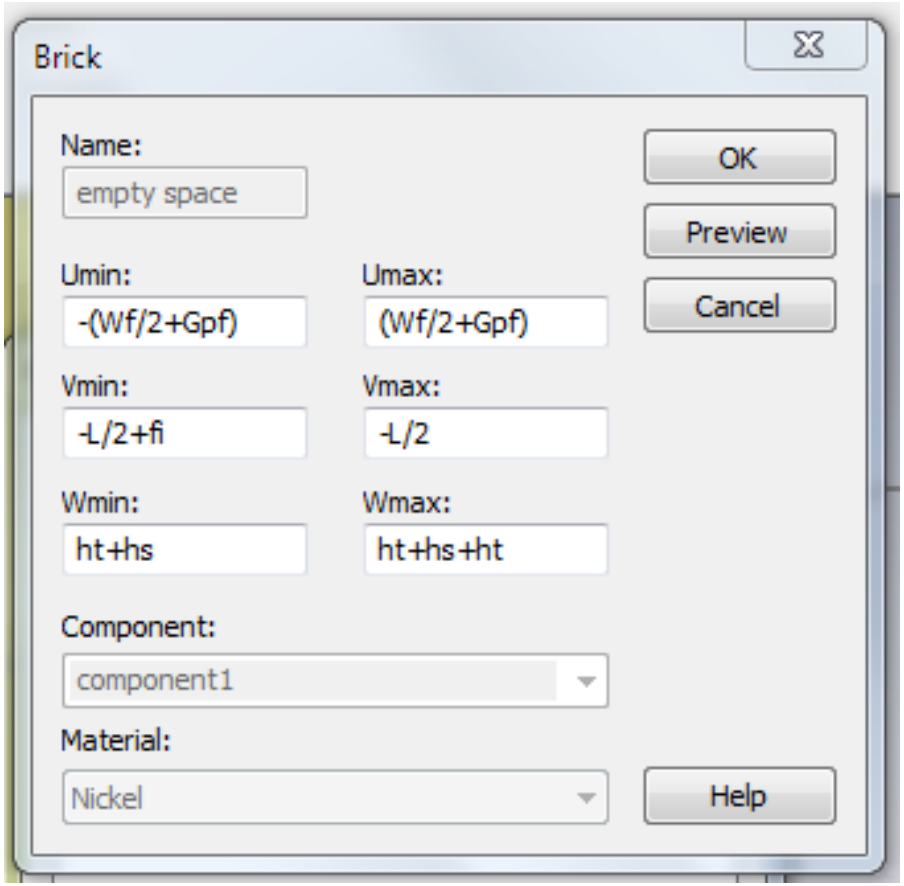


- Create the patch

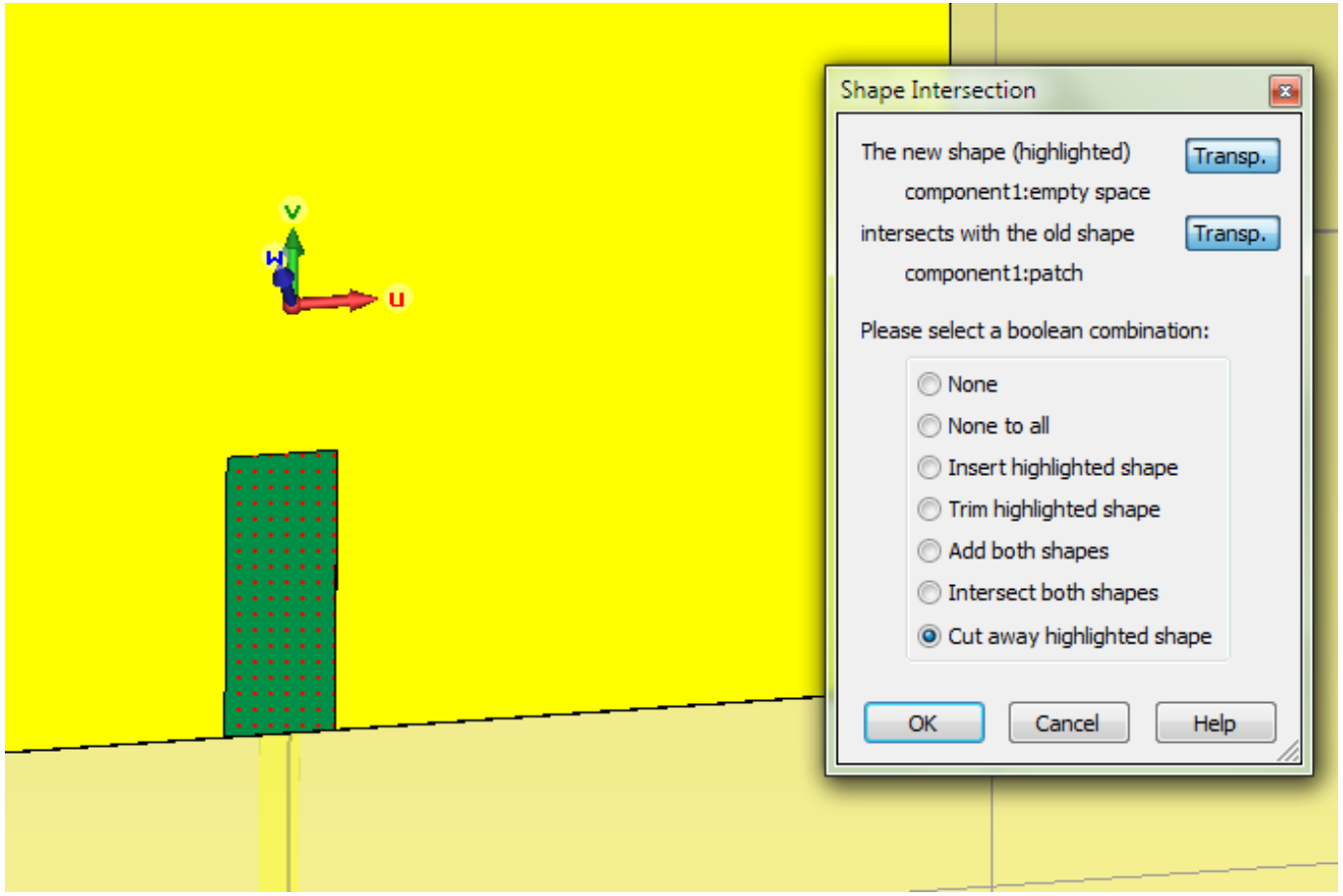




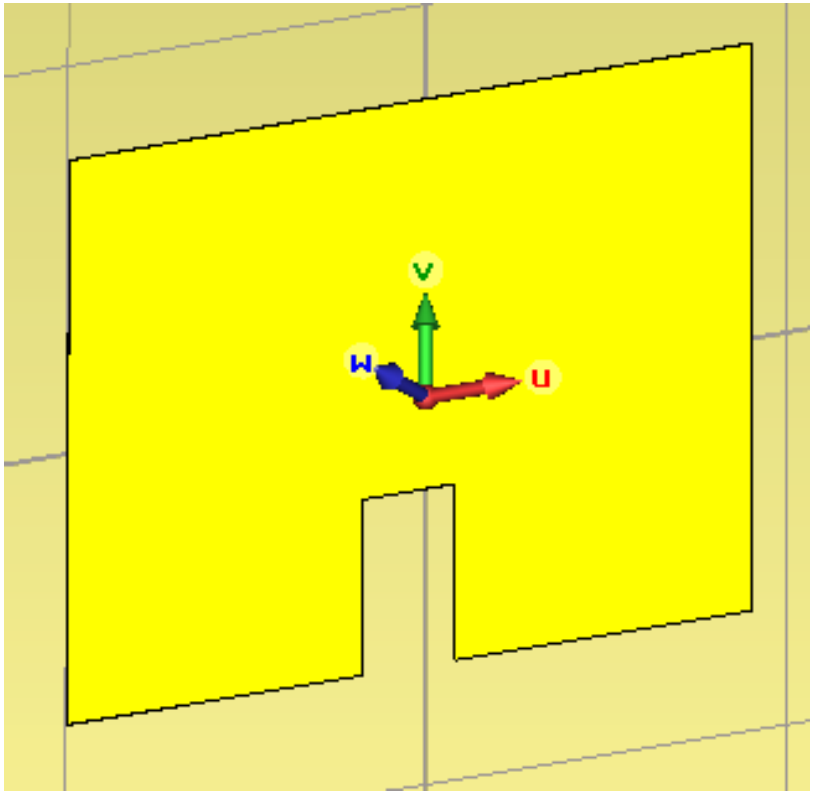
- Create the empty space



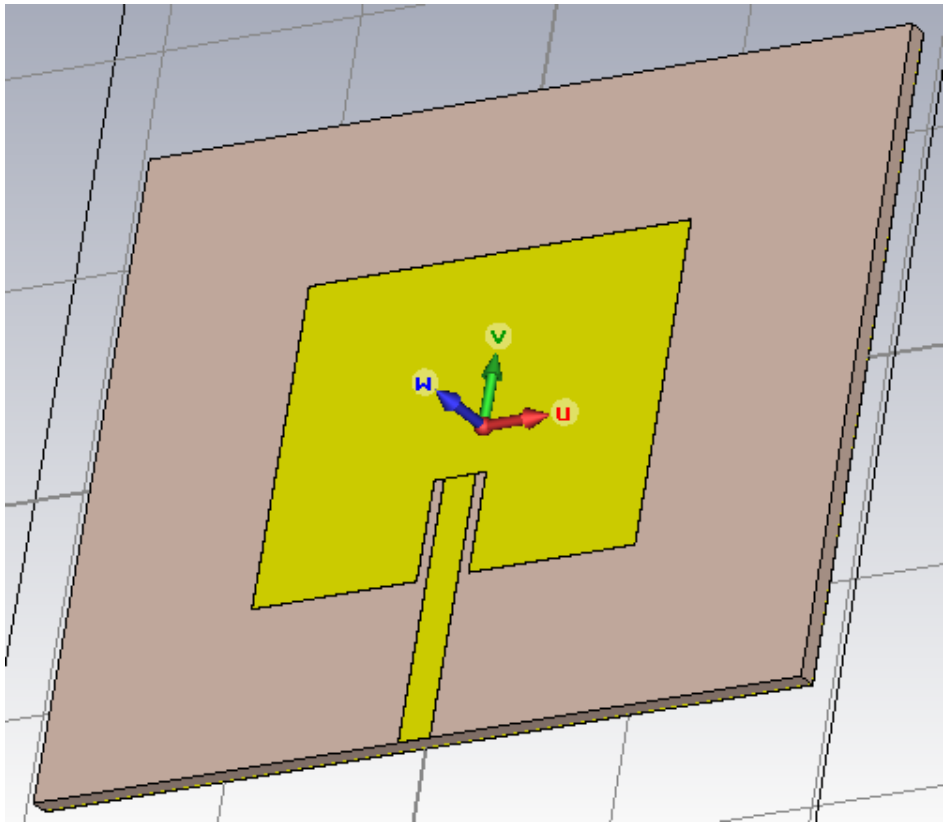
- Cut away the empty space

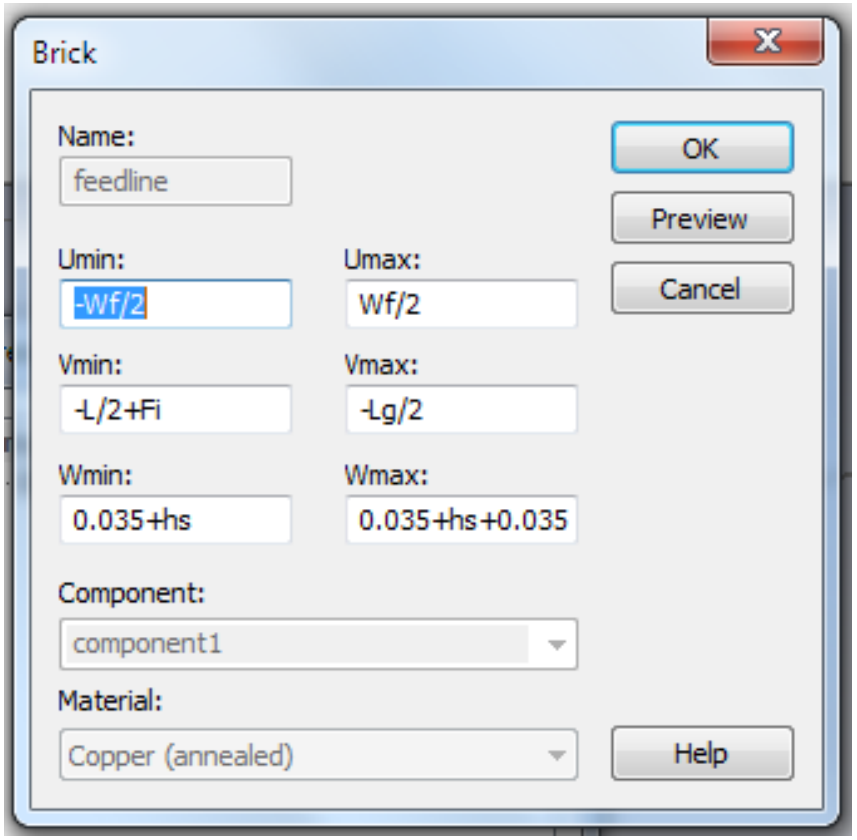


- Create the empty space



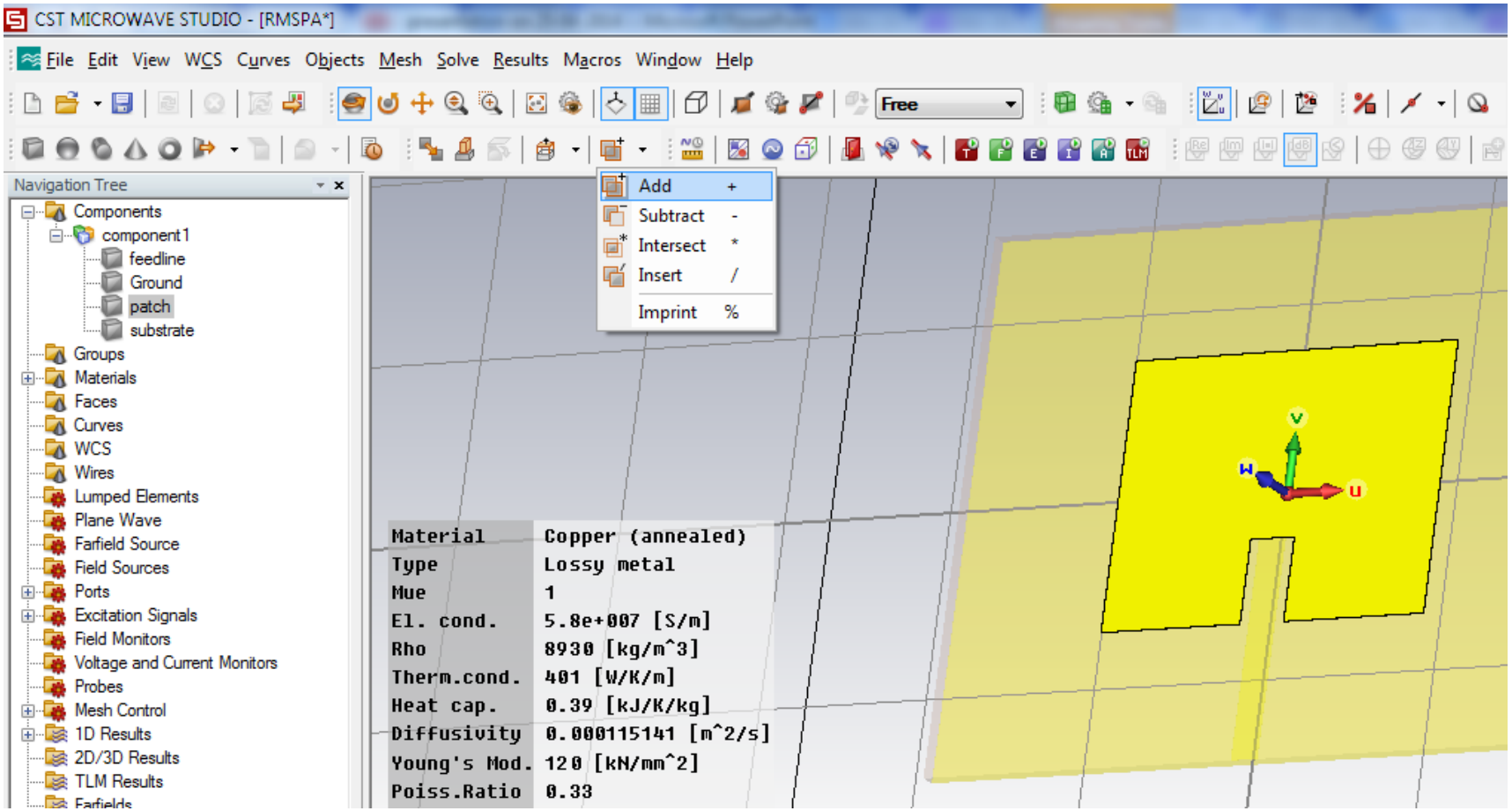
- Create the feed line



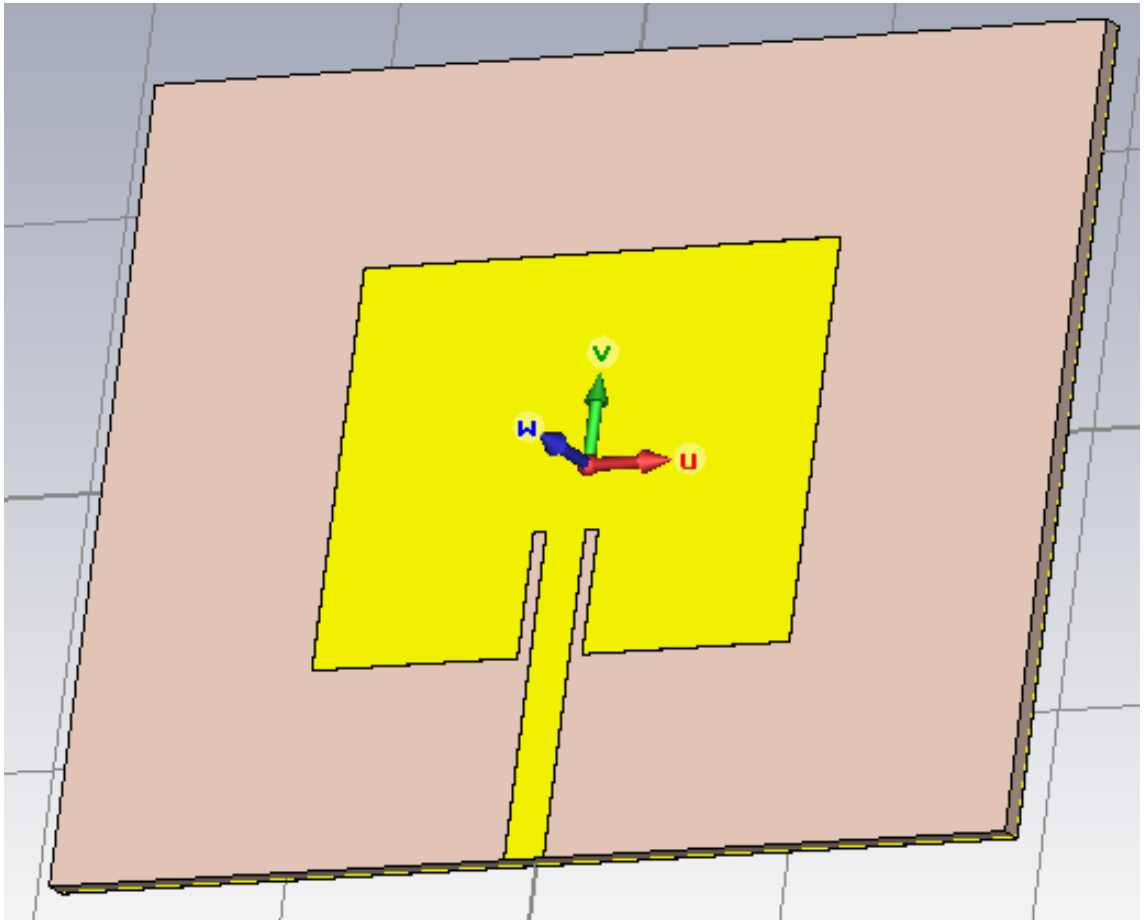


- The patch and feed line into one object

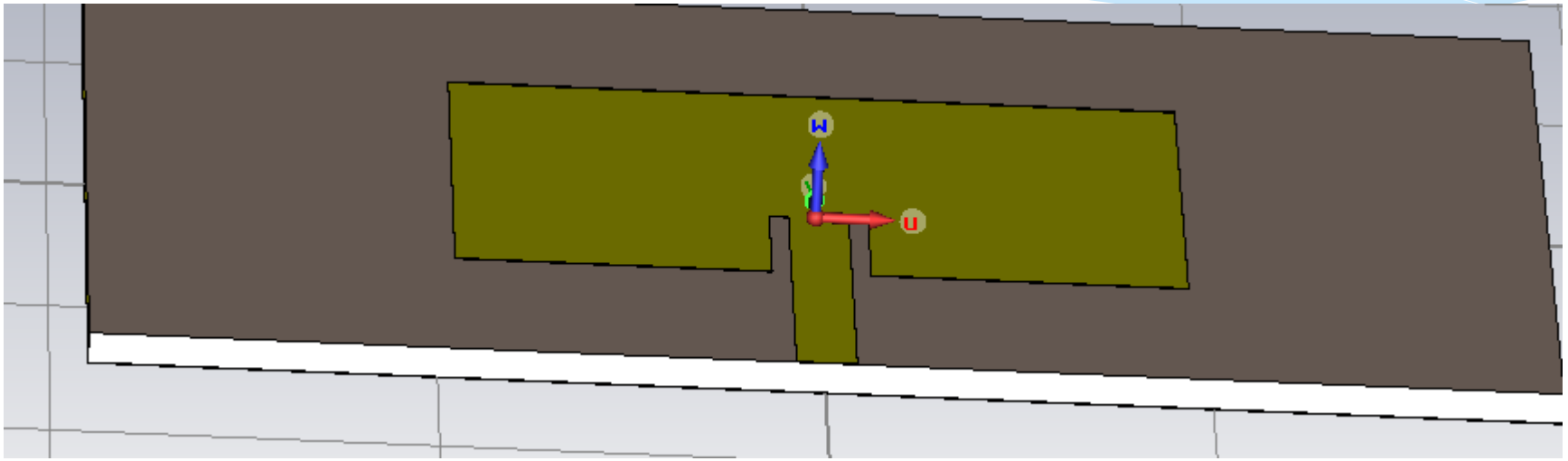
Press to patch then add then feedline then press Enter



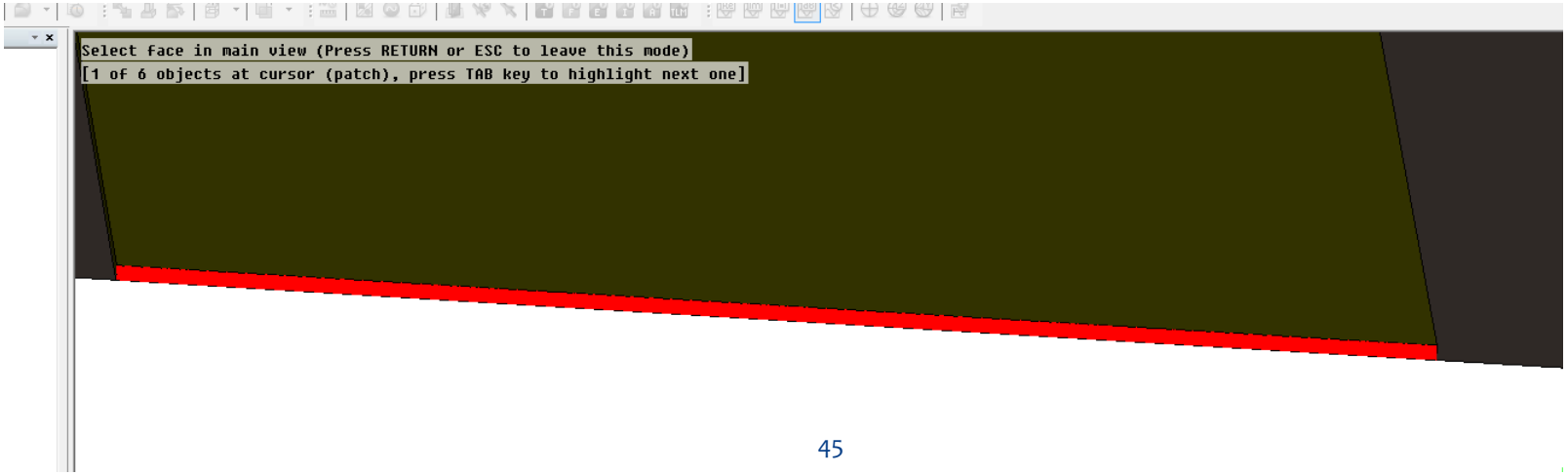
- The antenna



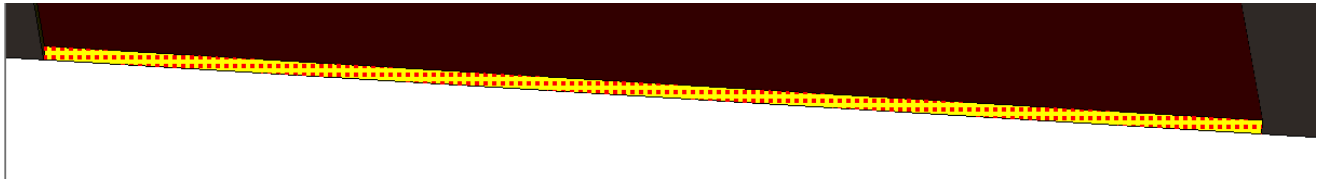
- The Port



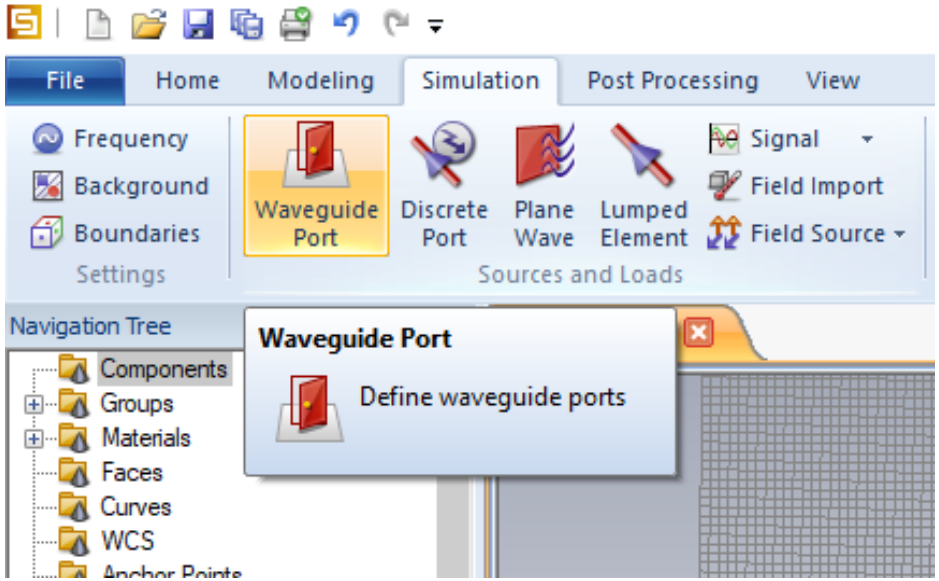
- Press F from in the keyboard and click to



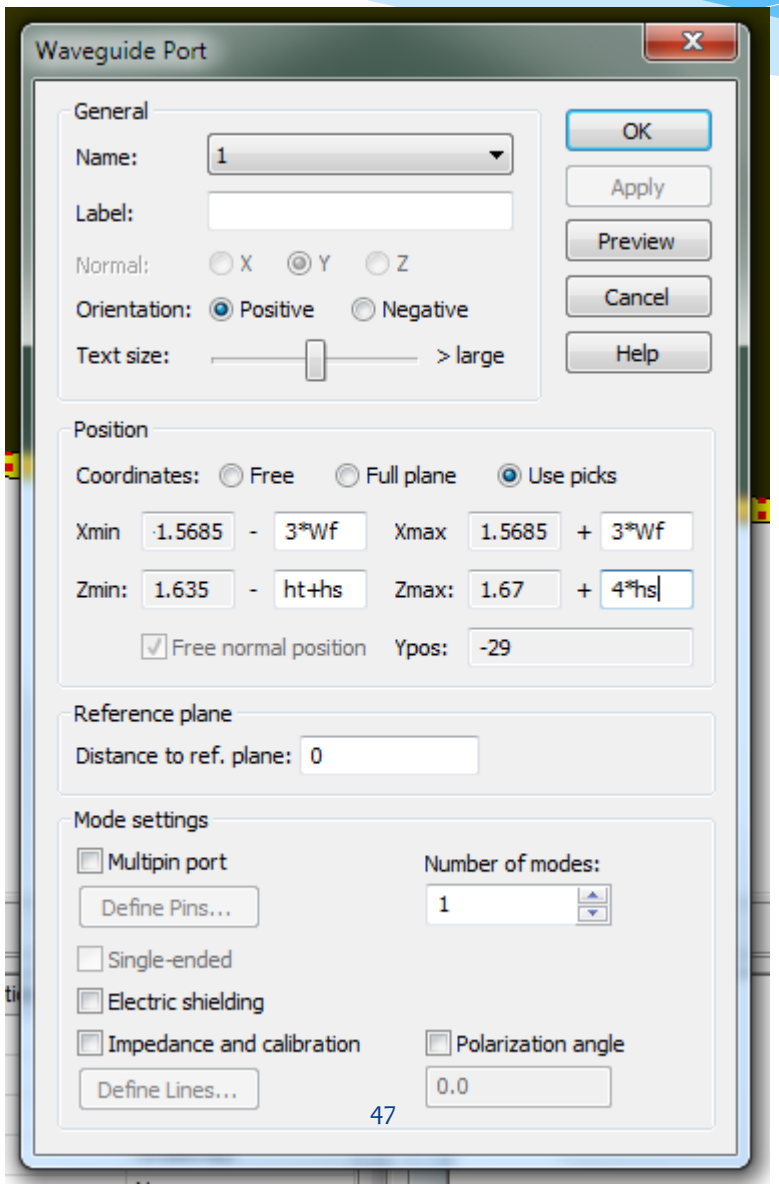
- Then



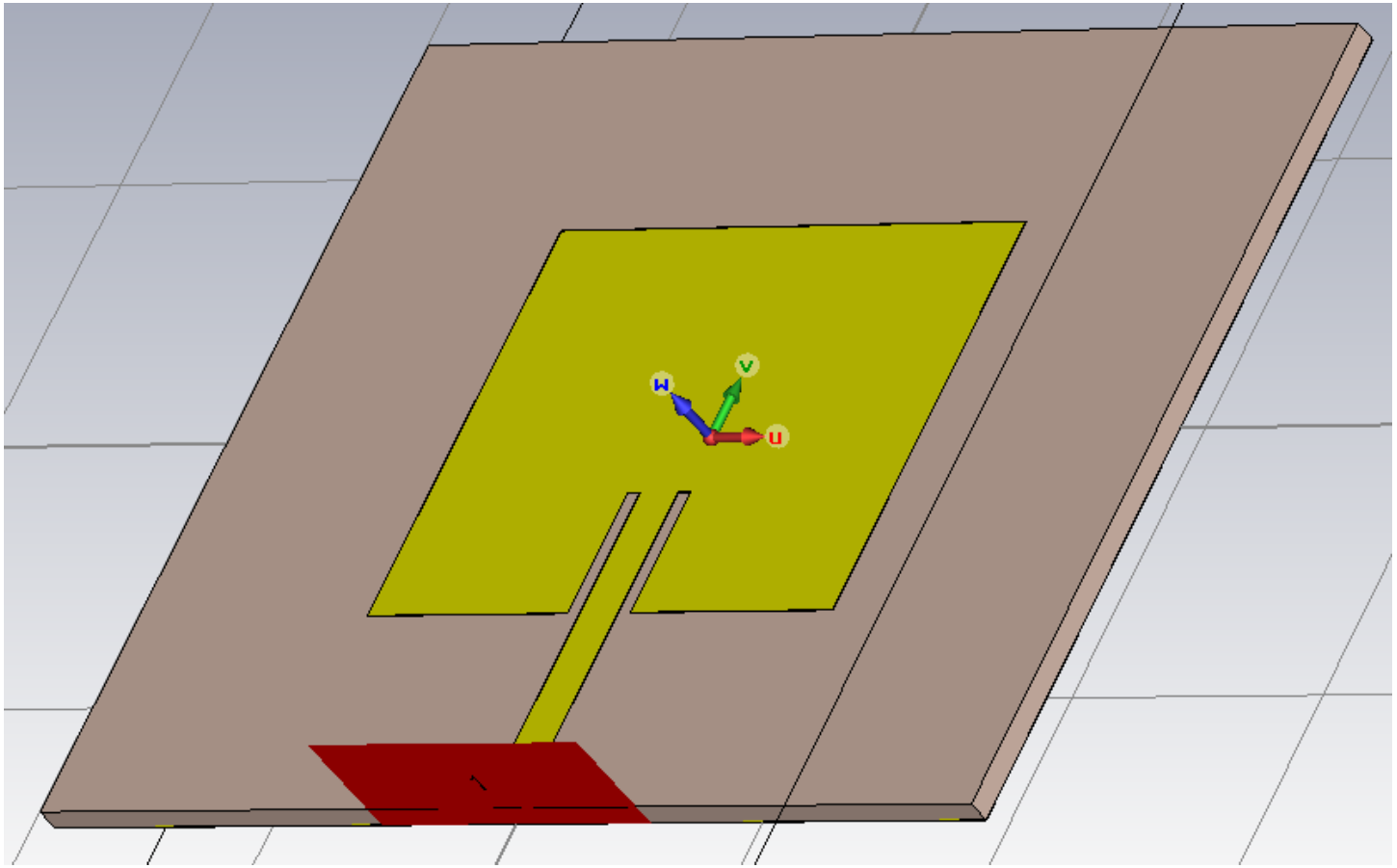
- click Simulation → waveguide port



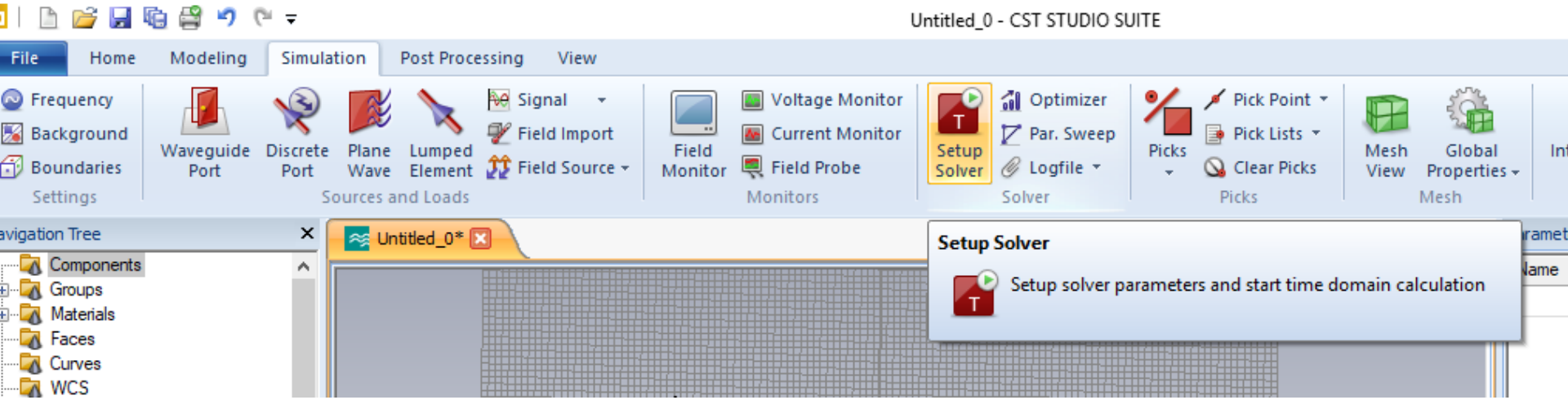
- waveguide port



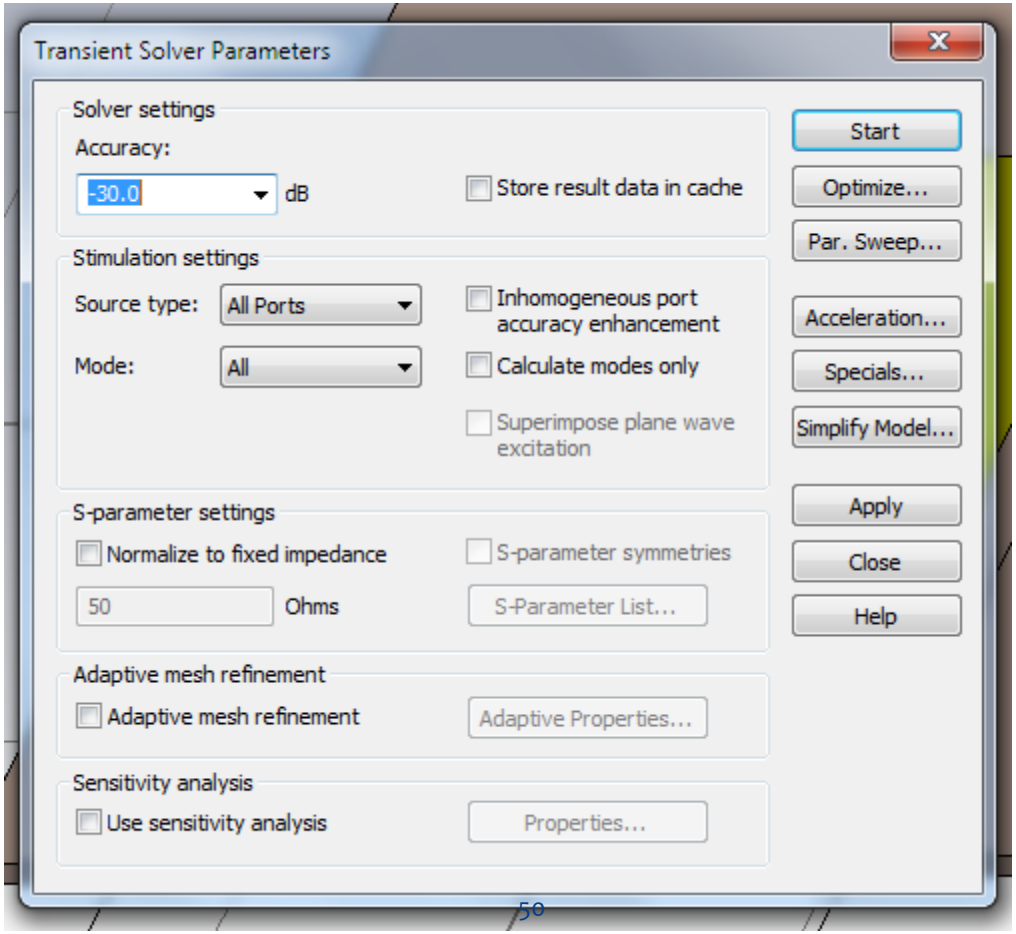
- The antenna is ready to simulated



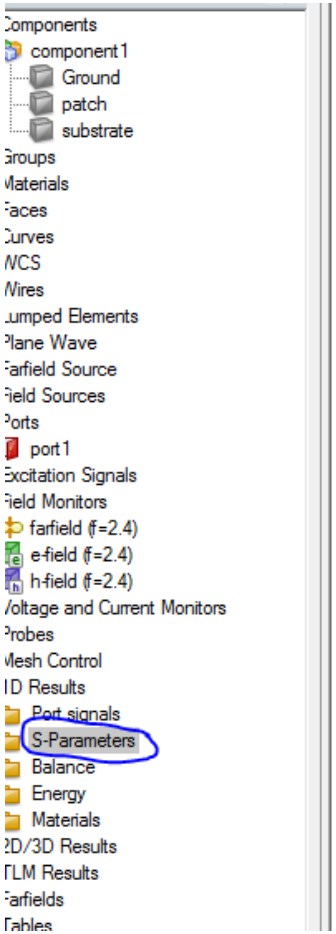
- click Simulation → Setup Solver

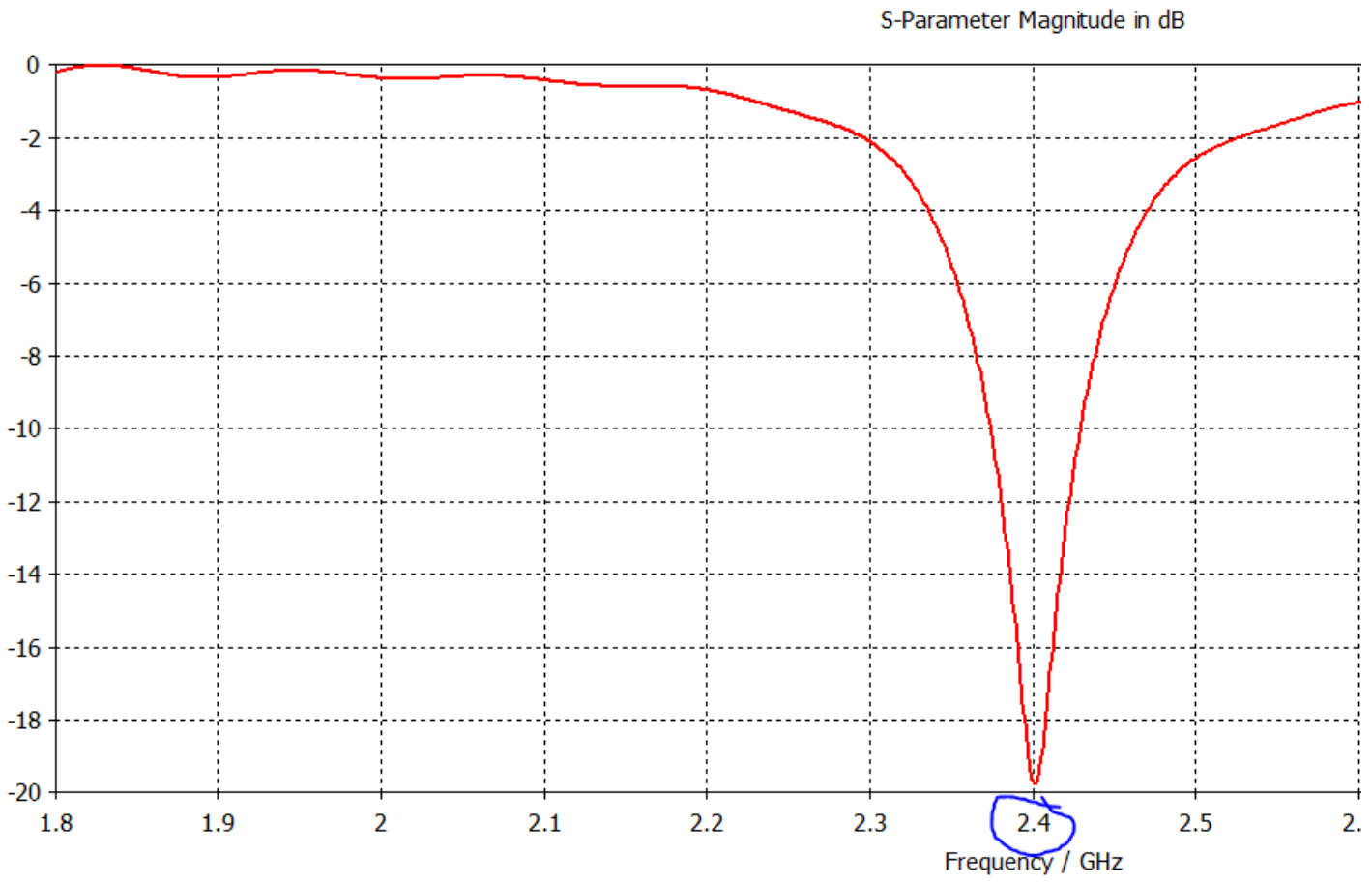


- start

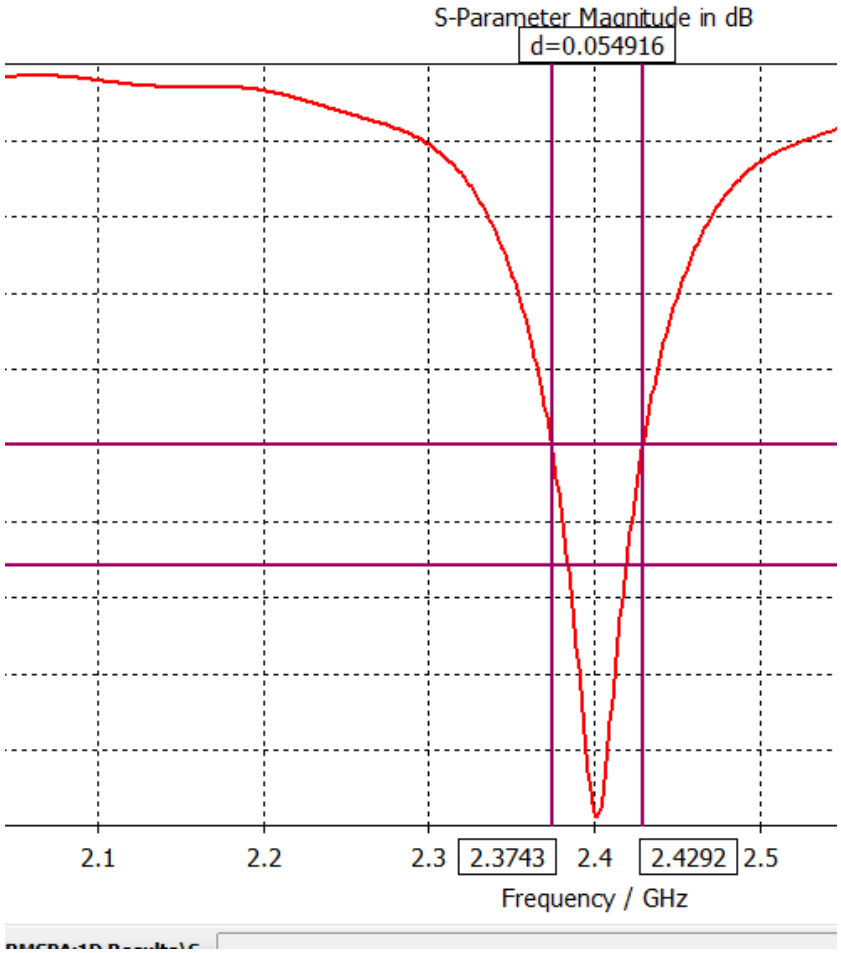

Transient Solver Parameters
Solver settings
Accuracy:
-30.0
dB
Store result data in cache
Stimulation settings
Source type:
All Ports
Mode:
All
Inhomogeneous port accuracy enhancement
Calculate modes only
Superimpose plane wave excitation
S-parameter settings
Normalize to fixed impedance
50
Ohms
S-parameter symmetries
S-Parameter List...
Adaptive mesh refinement
Adaptive mesh refinement
Adaptive Properties...
Sensitivity analysis
Use sensitivity analysis
Properties...
Start
Optimize...
Par. Sweep...
Acceleration...
Specials...
Simplify Model...
Apply
Close
Help

- The Result

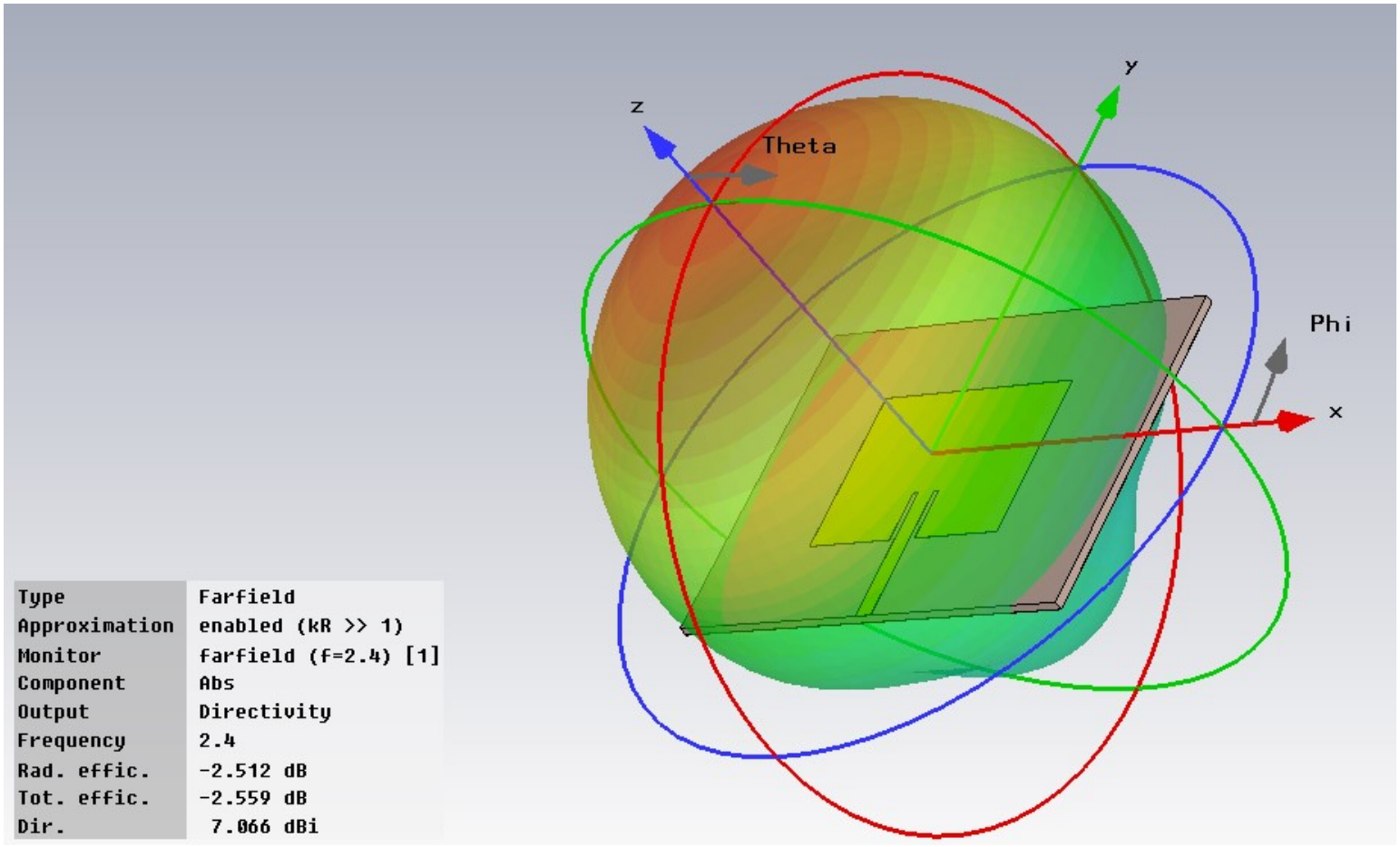

Components
component1
Ground
patch
substrate
Groups
Materials
Faces
Curves
WCS
Wires
Lumped Elements
Plane Wave
Farfield Source
Field Sources
Ports
port1
Excitation Signals
Field Monitors
farfield (f=2.4)
e-field (f=2.4)
h-field (f=2.4)
Voltage and Current Monitors
Probes
Mesh Control
1D Results
Port signals
S-Parameters
Balance
Energy
Materials
2D/3D Results
FEM Results
Farfields
Tables


S-Parameter Magnitude in dB
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
2.
Frequency / GHz

- The bandwidth = 54.9 MHz



- Fairfield Radiation pattern



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- Garg, Ramesh. 2001 “Microstrip antenna design handbook”, Artech House
- Ramesh, M and Yip KB, "Design Formula for Inset Fed Microstrip Patch Antenna", Journal of Microwave and Optoelectronics, Vol.3, No.3, December 2003.
- G. Devakirubai D et al., “Design and comparative study of pin feed and line feed microstrip patch antenna for x-band applications,” International Journal of Applied Information Systems, vol. 1, pp. 21–25, 2012.

Assignment

- Design and simulate a antenna for 5G (Sub – 6GHz frequency band) applications..
- Write a report detailing your work.
- Last date 12/04/2019.

upload the CST file and the report file

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thank you for your attentions