Patch Antenna Design Project

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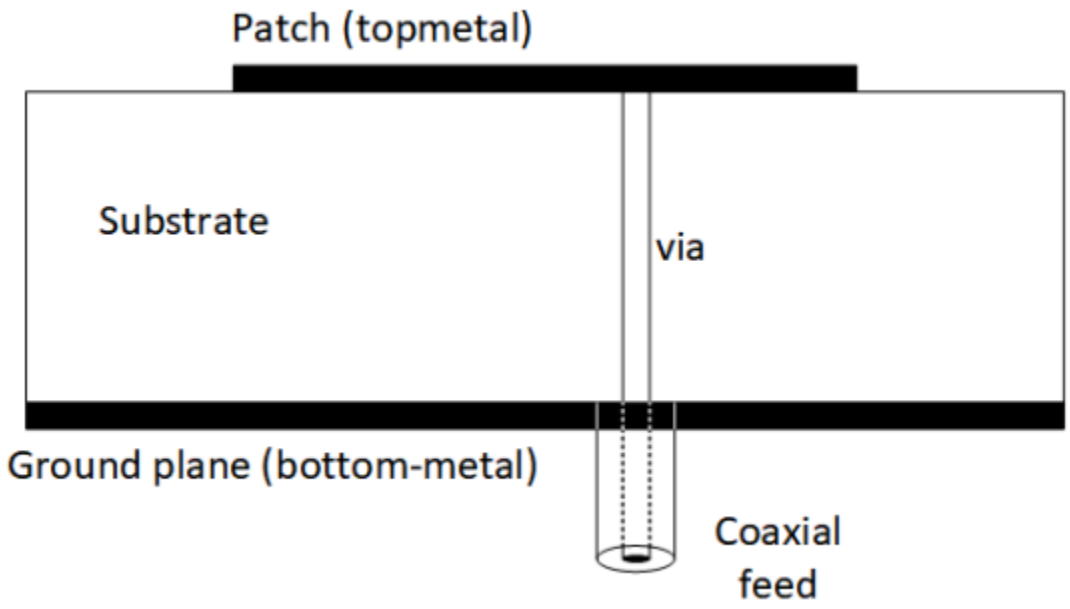
Assignment

Task and Design Requirements:

Design a patch antenna fed by coax cable that can be used in a 4-element array

Design

The patch antenna is structured as follows and must meet the requirements below:



ID	Parameter	Requirement
1	Operating bandwidth	5.725 – 5.875 GHz
2	Port match	$S_{11} < -10dB$ @ $Z_0 = 50\Omega$
3	Radiation efficiency	$\eta_{rad} > 80\%$
4	Antenna gain	6dBi
5	Simulation setup	Make use of a symmetry plane in CST

The design equations are as follows as found at www.everythingrf.com/microstrip-patch-antenna-calculator:

The Microstrip Patch Antenna Calculation Process

Step 1: Calculation of the Width (W) -

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

Step 2: Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Step 3: Calculation of the Effective length

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

Step 4: Calculation of the length extension ΔL

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

Step 5: Calculation of actual length of the patch

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

Where the following parameters are used

f_0 is the Resonance Frequency

W is the Width of the Patch

L is the Length of the Patch

h is the thickness

ε_r is the relative Permittivity of the dielectric substrate

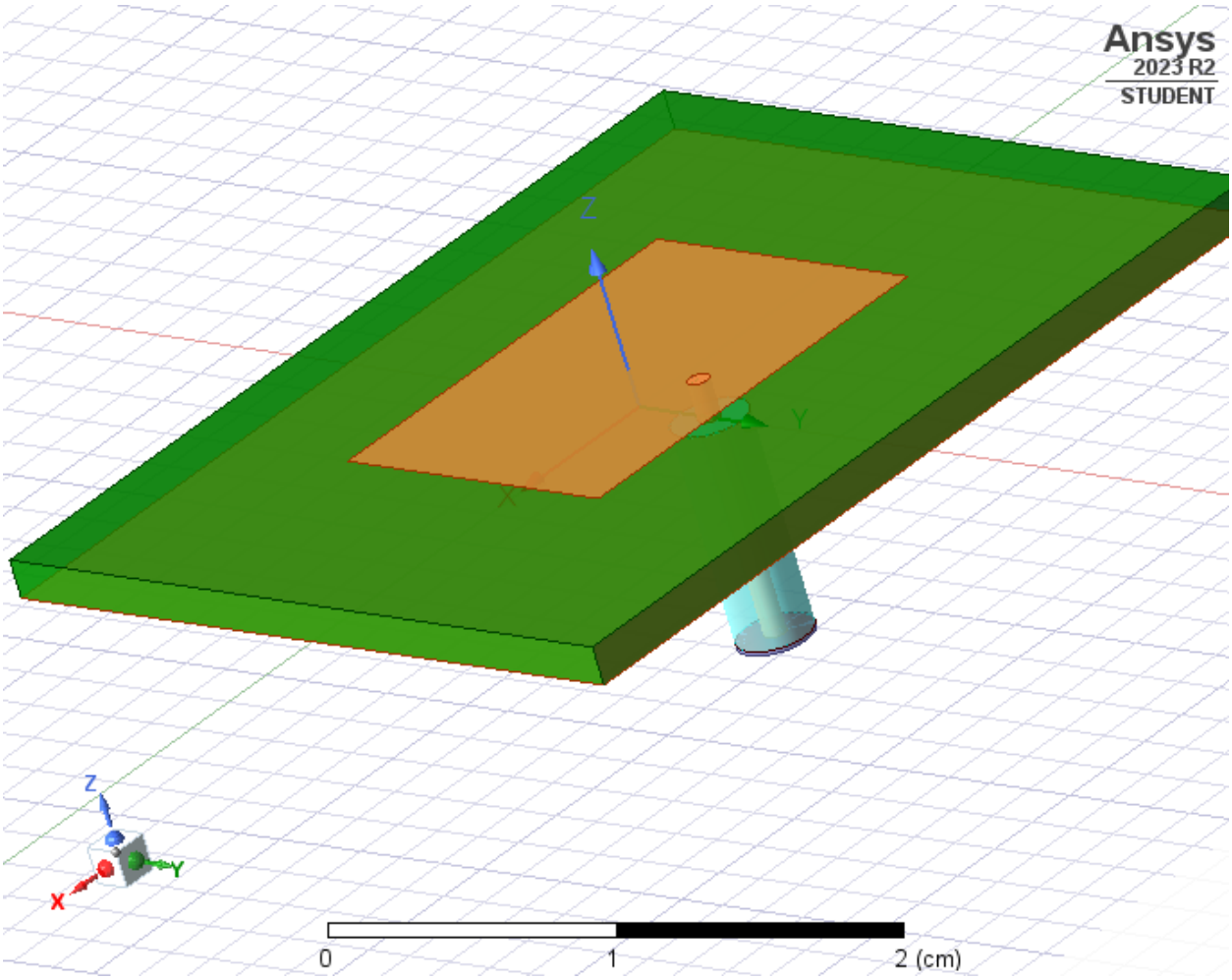
c is the Speed of light: 3×10^8

For this design, the center frequency equals 5.8 GHz, and the substrate is Rogers 4350B with a height of 1.52 mm and an effective dielectric constant of 3.66.

After inputting those parameters, the following dimensions were calculated:

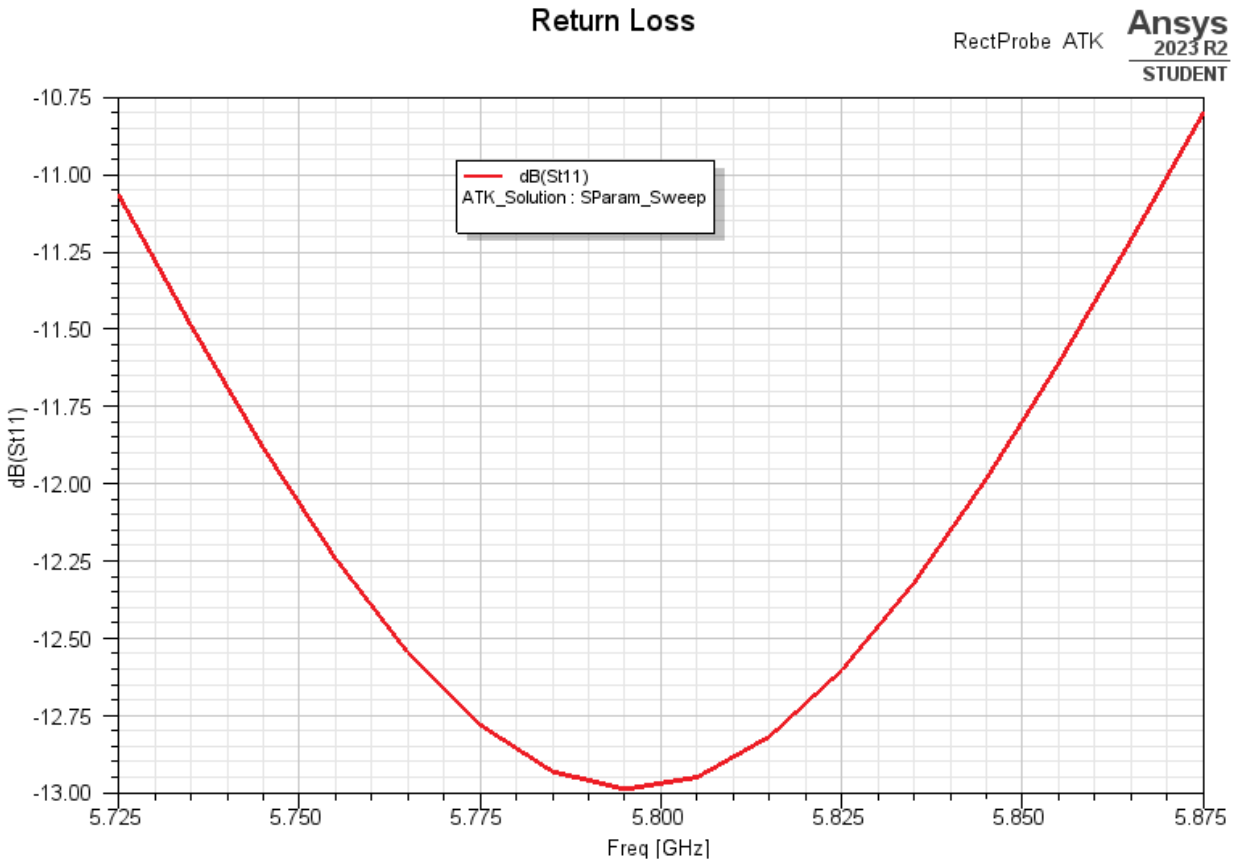
Name	Value	Unit
"--Antenna Dimensions"		
patchX	1.657	cm
patchY	1.247	cm
"--Substrate Dimensions"		
subH	0.152	cm
subX	3.5	cm
subY	2.9	cm
"--Feed Dimensions"		
feedX	0	cm
feedY	0.35	cm
coax_inner_rad	0.043	cm
coax_outer_rad	0.147	cm
feedLength	0.86	cm

The following picture is the HFSS patch antenna:

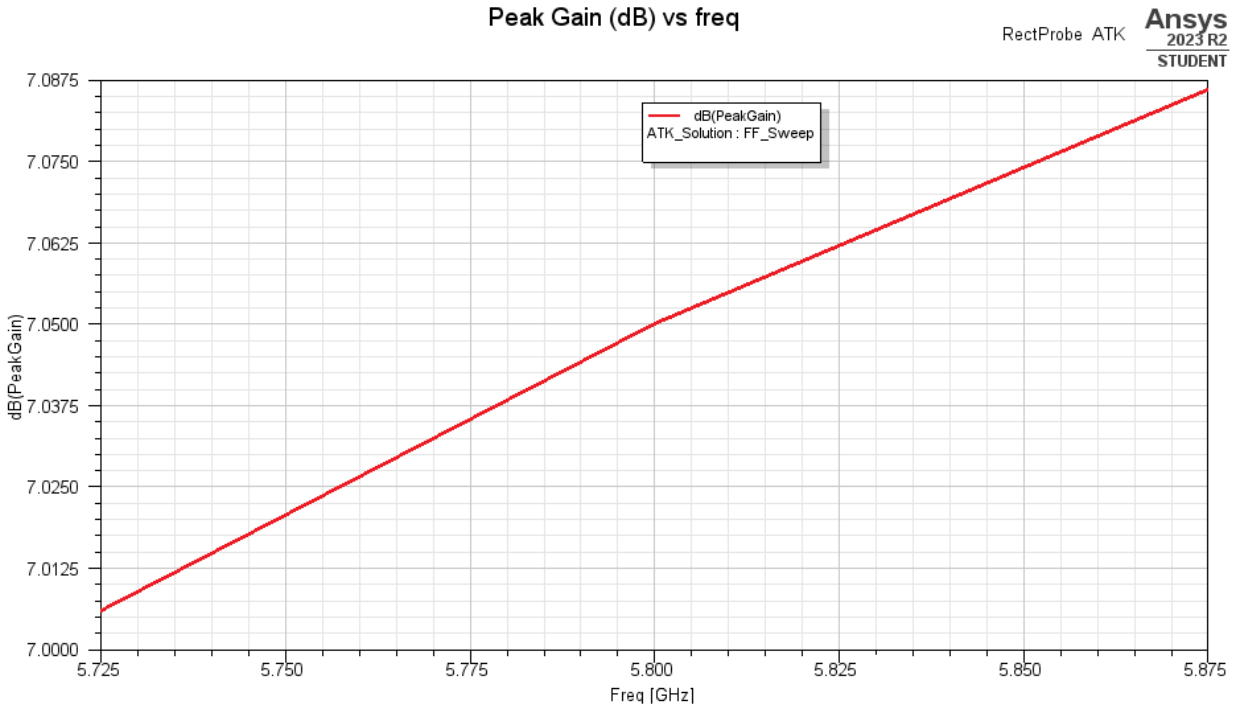


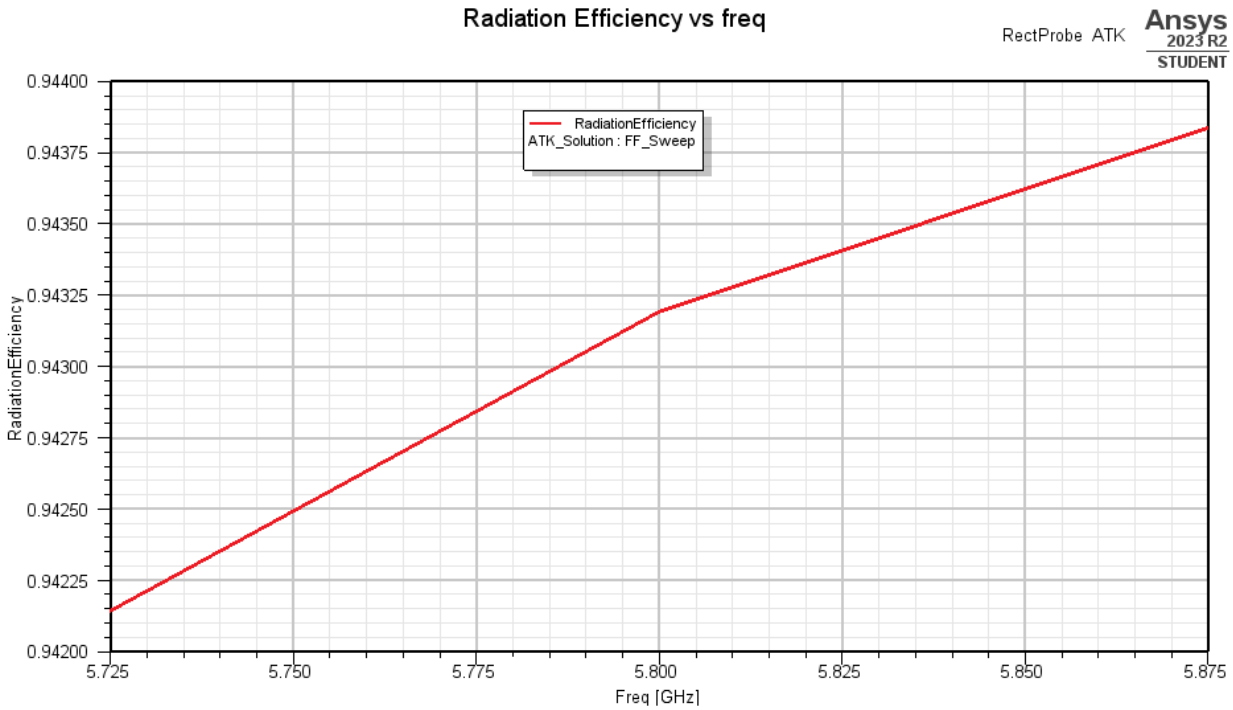
Analysis

Using HFSS, the following graphs were generated. The only difficulty was the location of the feed, which was first put at 0.23 cm, which resulted in a very high return loss. After some adjustment, it was found that a location of 0.35 cm brought the return loss to under -10dB through the operating region (5.725 to 5.875 GHz):



The peak gain is found to be greater than 6 dBi for all frequencies of interest:





The above plot shows that the radiation efficiency is well above 80% for all frequencies of interest.

Conclusion

A patch antenna meeting the given requirements was successfully designed in HFSS (as the links to the other software packages were broken), after the adjustment was made to the location of the input coax connector (moved from 0.23 mm to 0.35 mm from the center of the patch. This simulation is an estimate of behavior, which does not include, for example, fringing effects and mutual coupling among antennas (this is designed to be part of a 4-element phased array).

References

A.B Smolder, H. J. Visser, U. Johannsen. Modern Antennas and Microwave Circuits: A complete master-level course. Version September 2020. Eindhoven University of Technology.

www.everythingrf.com/rf_calculators/microstrip-patch-antenna-calculator/