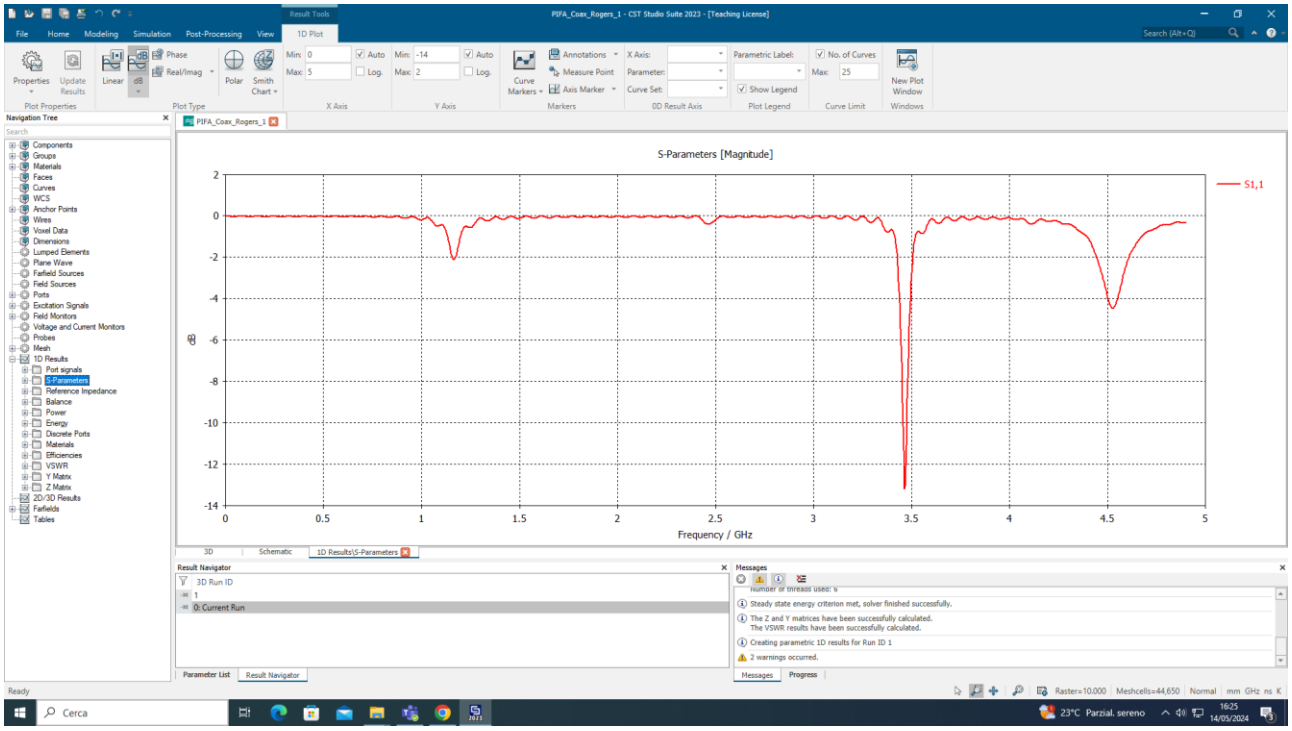
# PIFA Antenna Design and Tuning

## 1. Introduction

This laboratory project focuses on the **design and tuning of a PIFA antenna** using **CST Studio Suite**. Starting from the assigned CST model (a PIFA tuned at 3.45 GHz), the goal was to re-tune the antenna to operate at **3.2 GHz**.

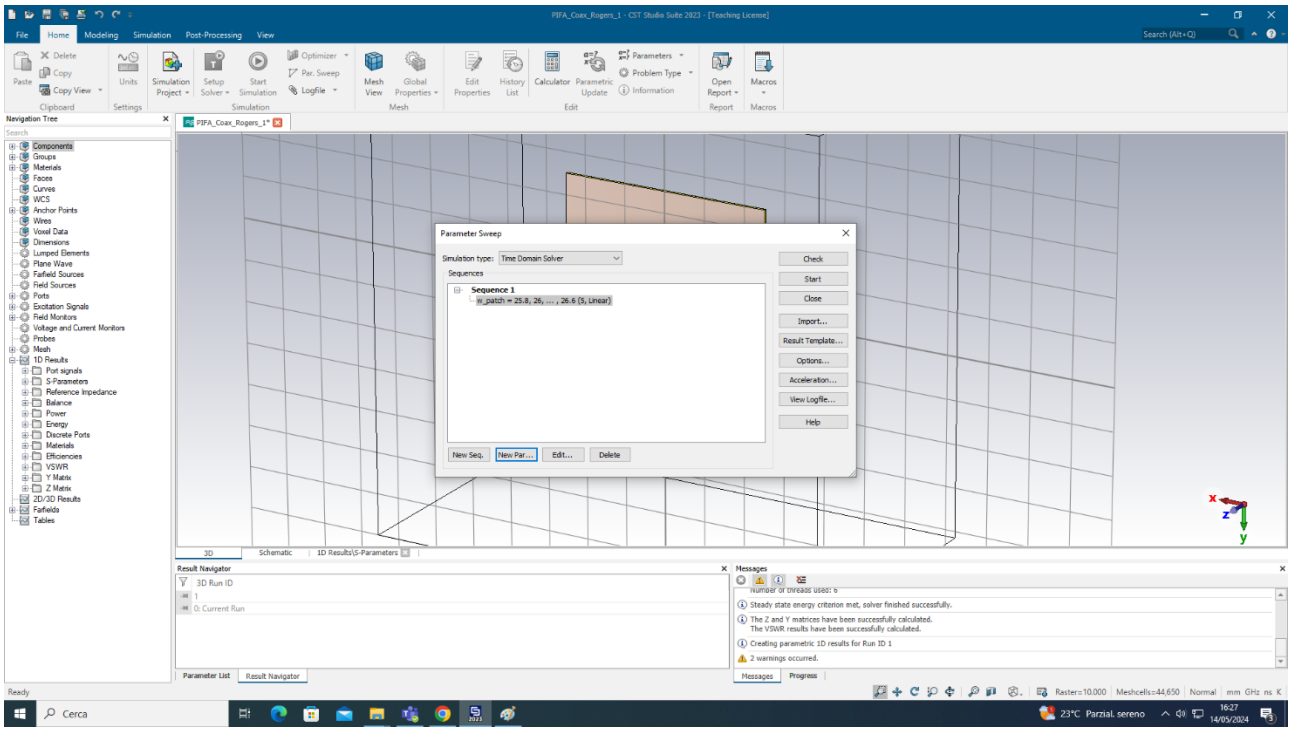
An initial simulation of the provided antenna, without any modification, shows that it resonates at 3.45 GHz. This behavior is confirmed by the **S11 reflection coefficient**, with a return loss of about **–13 dB** at 3.45 GHz.

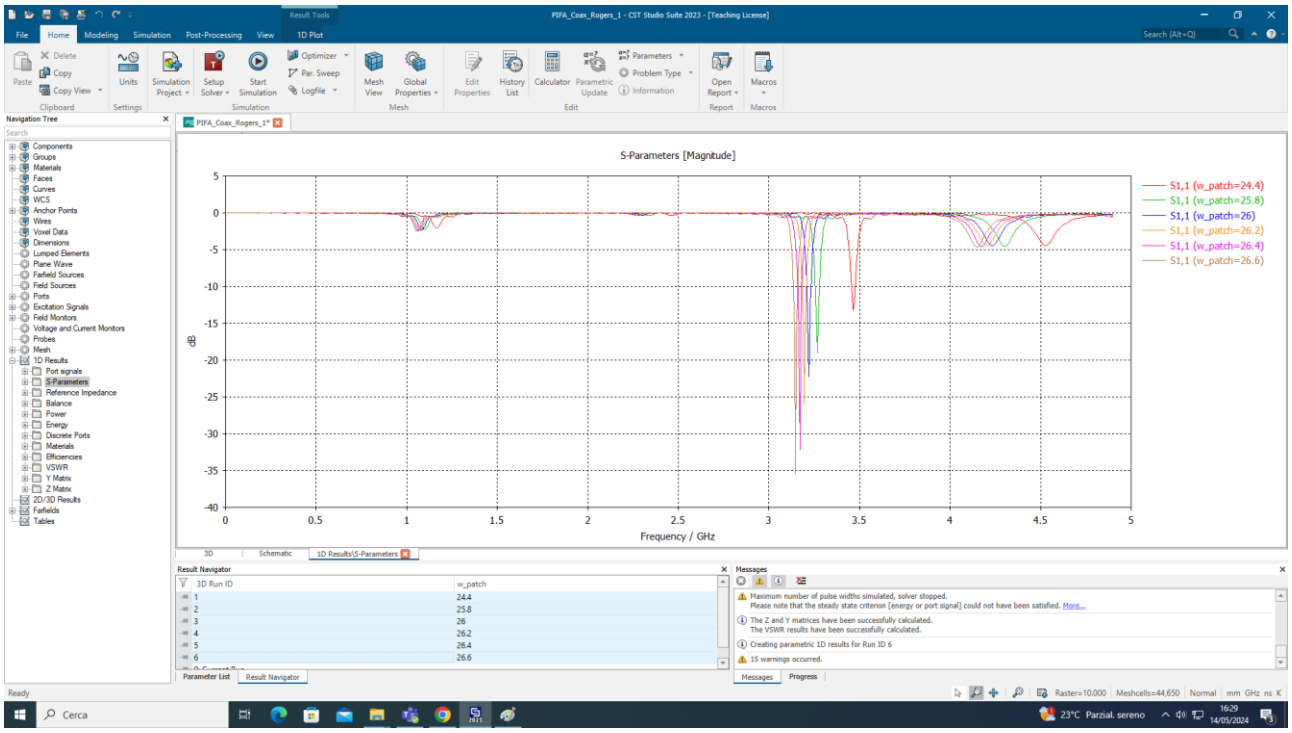



## 2. Parameter Sweep and Tuning with Rogers Substrate

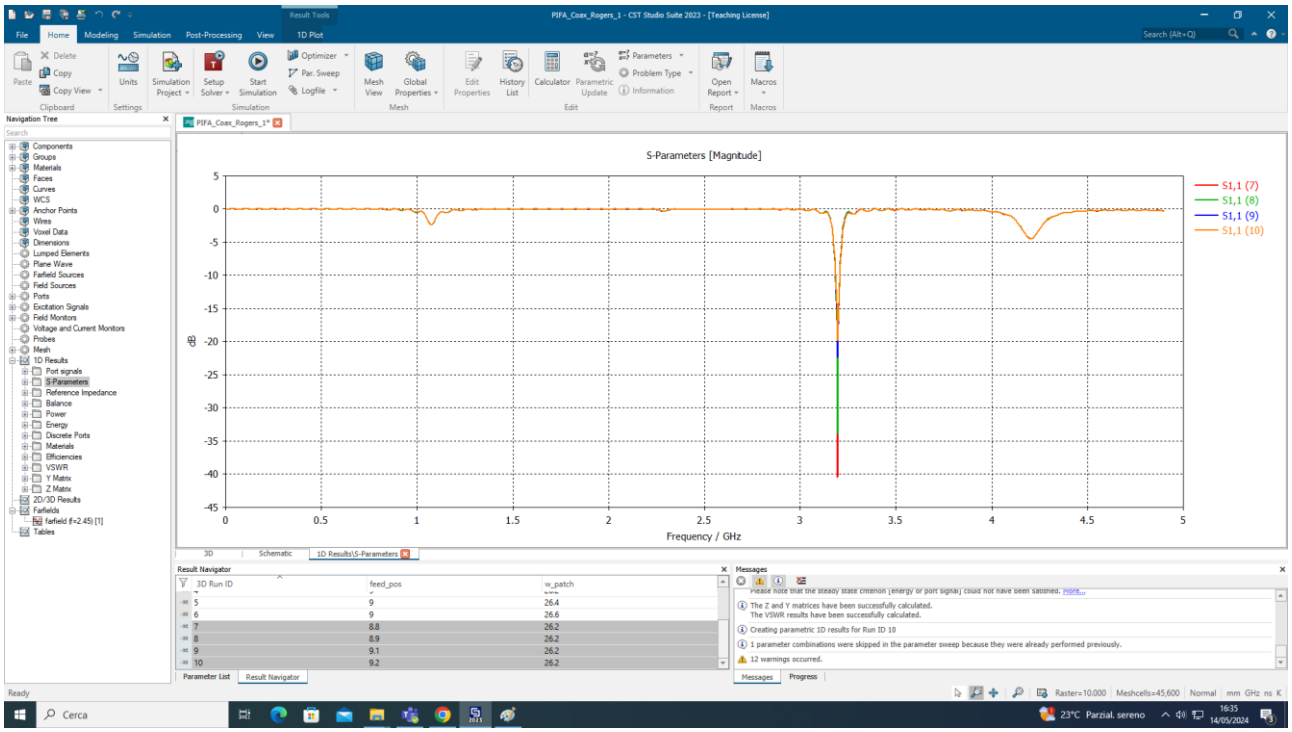
To properly tune the antenna, it is necessary to adjust some parameters in order to shift its operating frequency. By using the **parameter sweep** function, a series of consecutive simulations can be performed where the chosen parameter is varied within a defined range.

As an initial step, a parameter sweep was carried out on the **patch width** (which, in this case, also corresponds to its length).



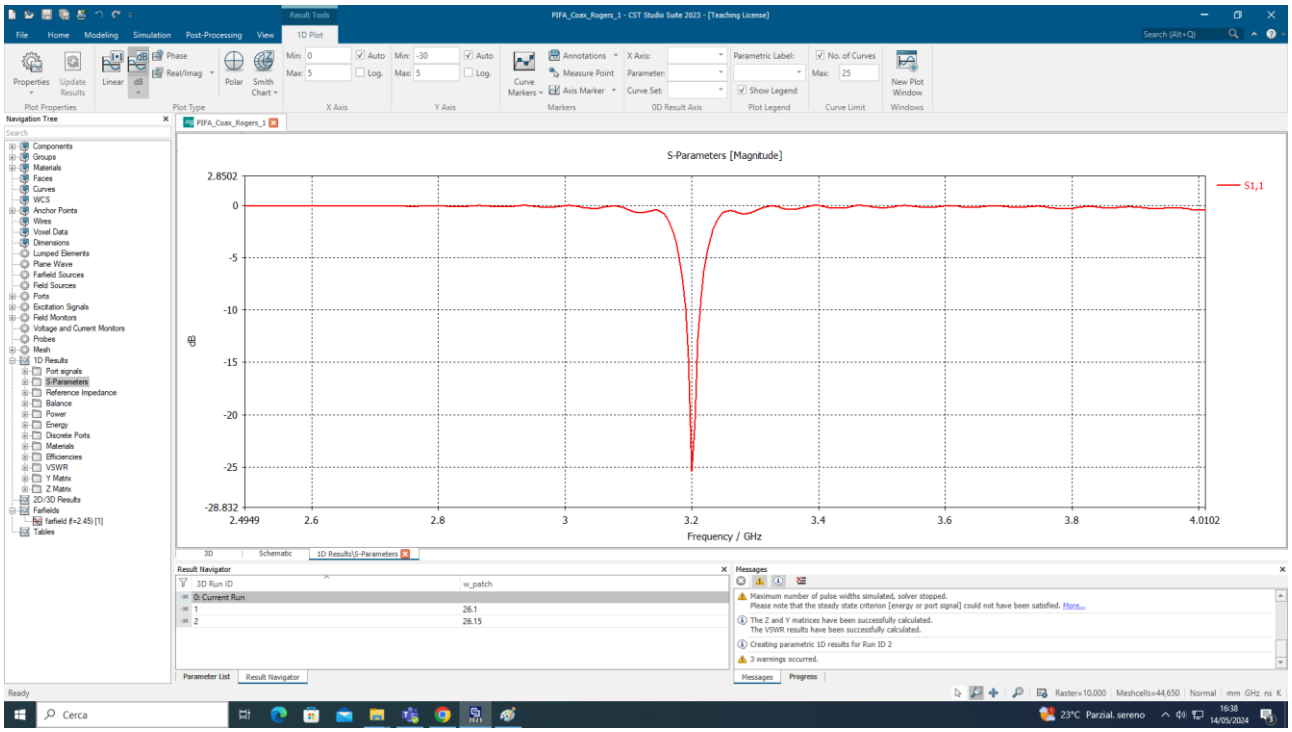




The sweep results indicated that a **width of 26.2 mm** shifts the resonance close to the desired frequency of 3.2 GHz. A subsequent sweep was then conducted on the **feeding position**, to refine the tuning.




As highlighted in the figure, by varying the feeding position it is possible to achieve a deeper attenuation at the desired frequency while remaining close to the previous values. After a series of iterations, the optimal tuning parameters were identified as:

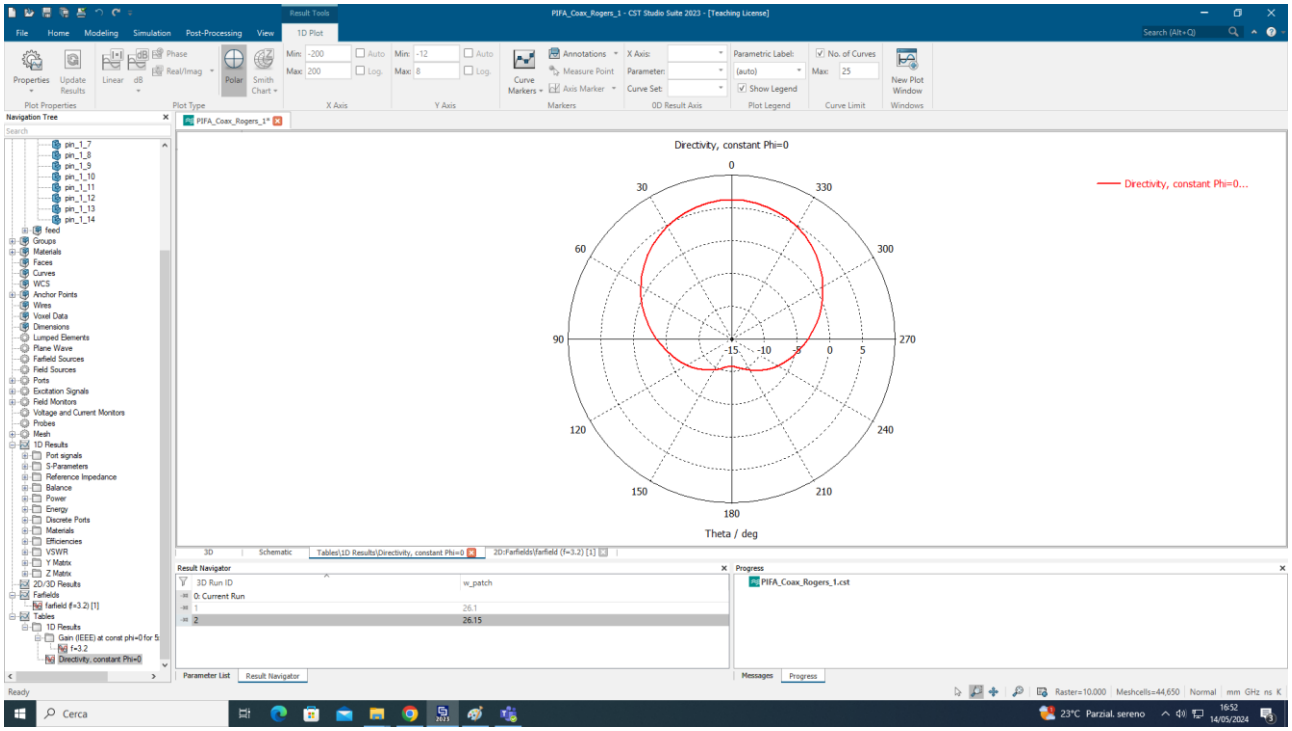
- Patch width: **26.15 mm**
- Feeding position: **8.9 mm**

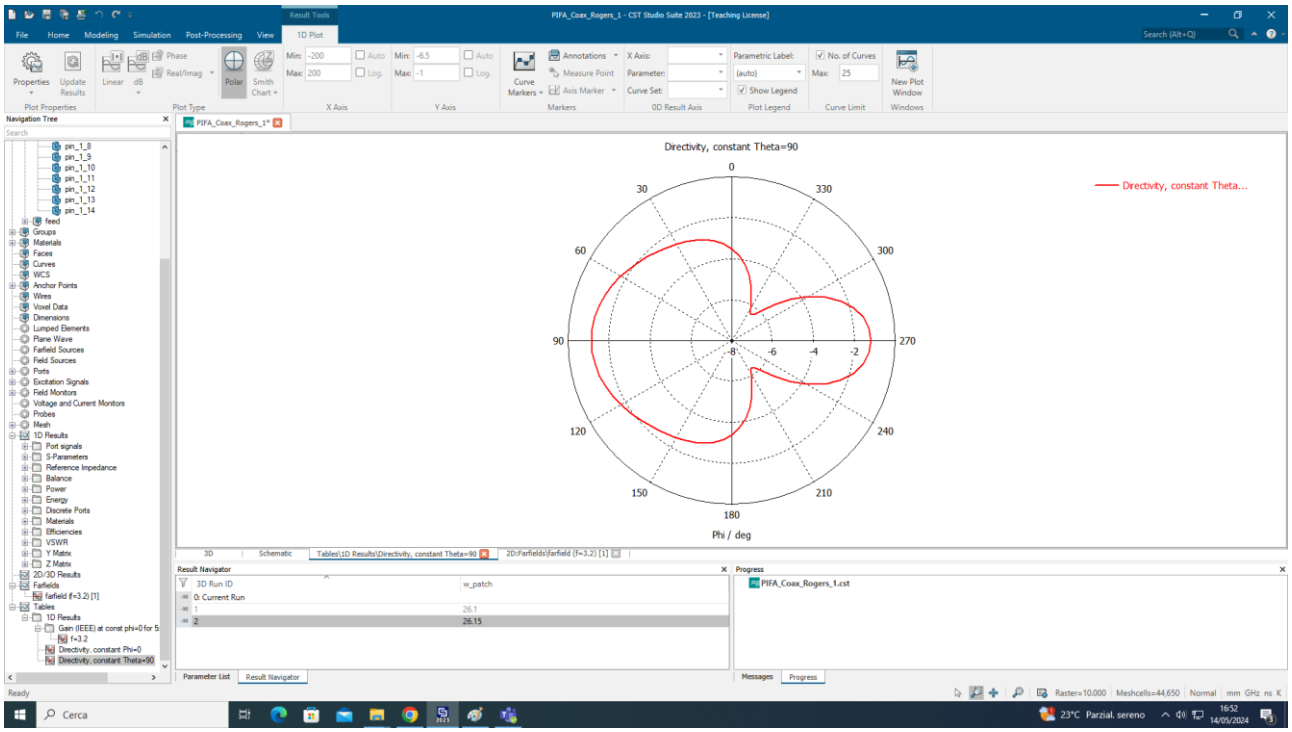


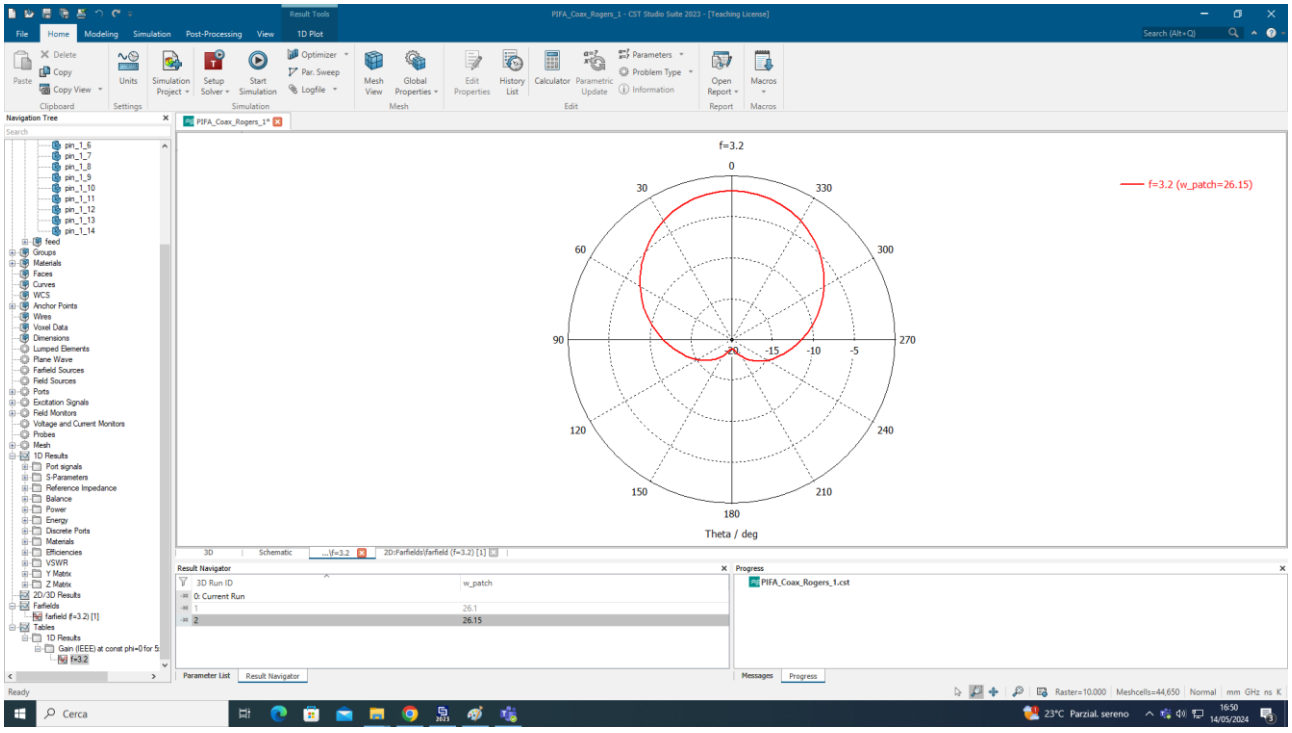
The result is an antenna perfectly tuned at 3.2 GHz with an attenuation of about **–25 dB**. It is worth noting that, at this stage, no further modifications were required and the antenna pins remained unchanged.

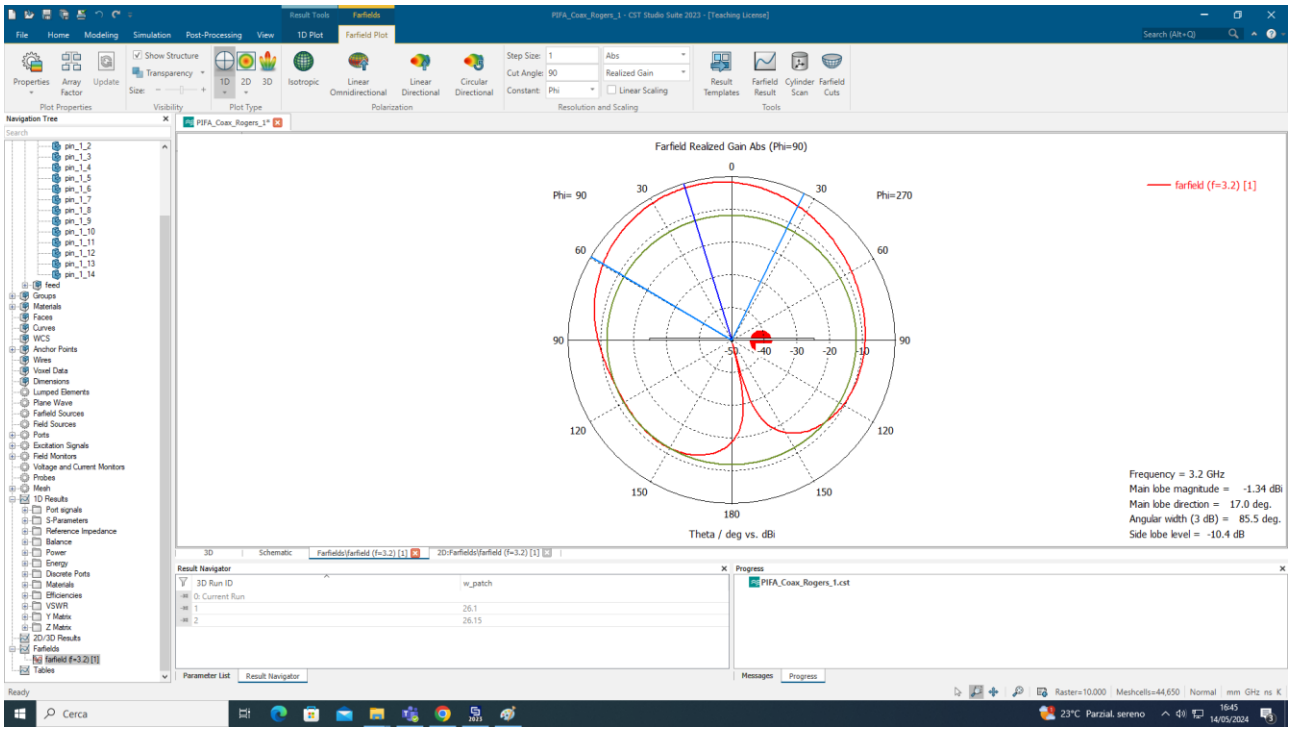
The obtained results include:

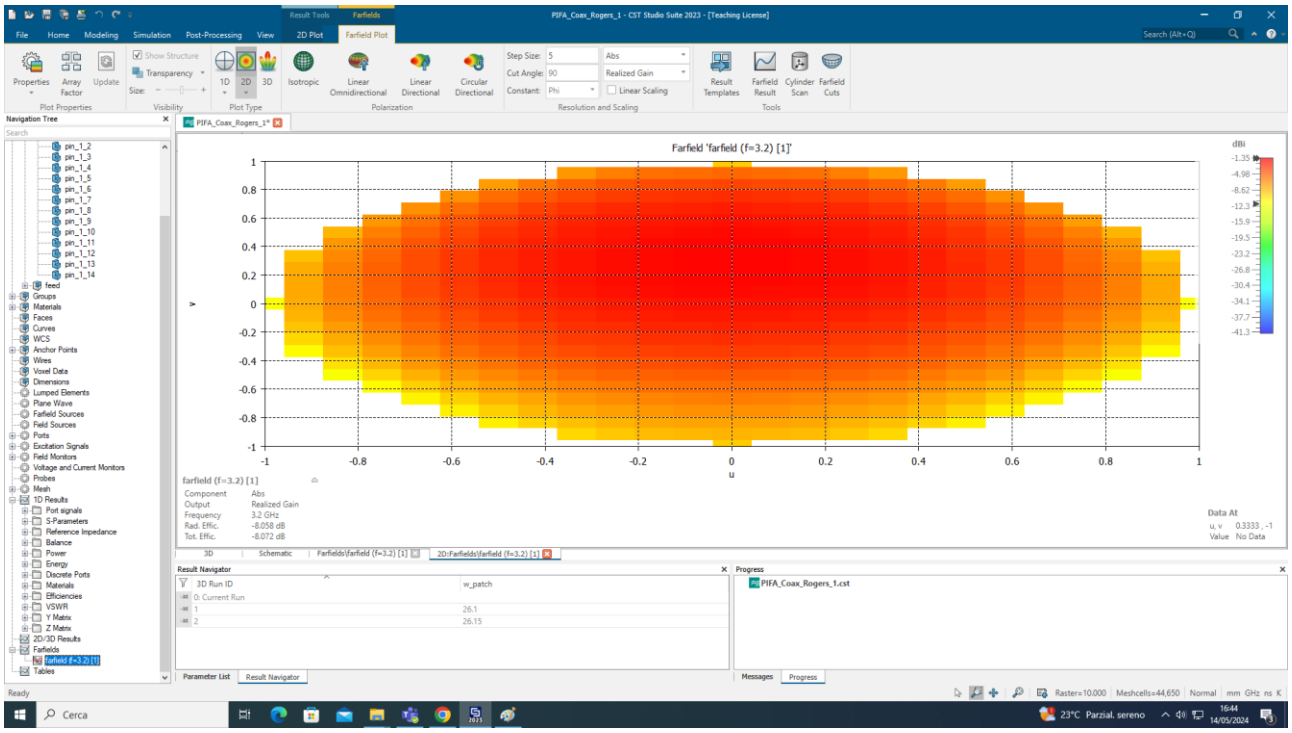
- Directivity
- IEEE Gain
- Realized Gain
- 2D radiation diagrams
- Far-field 3D plots

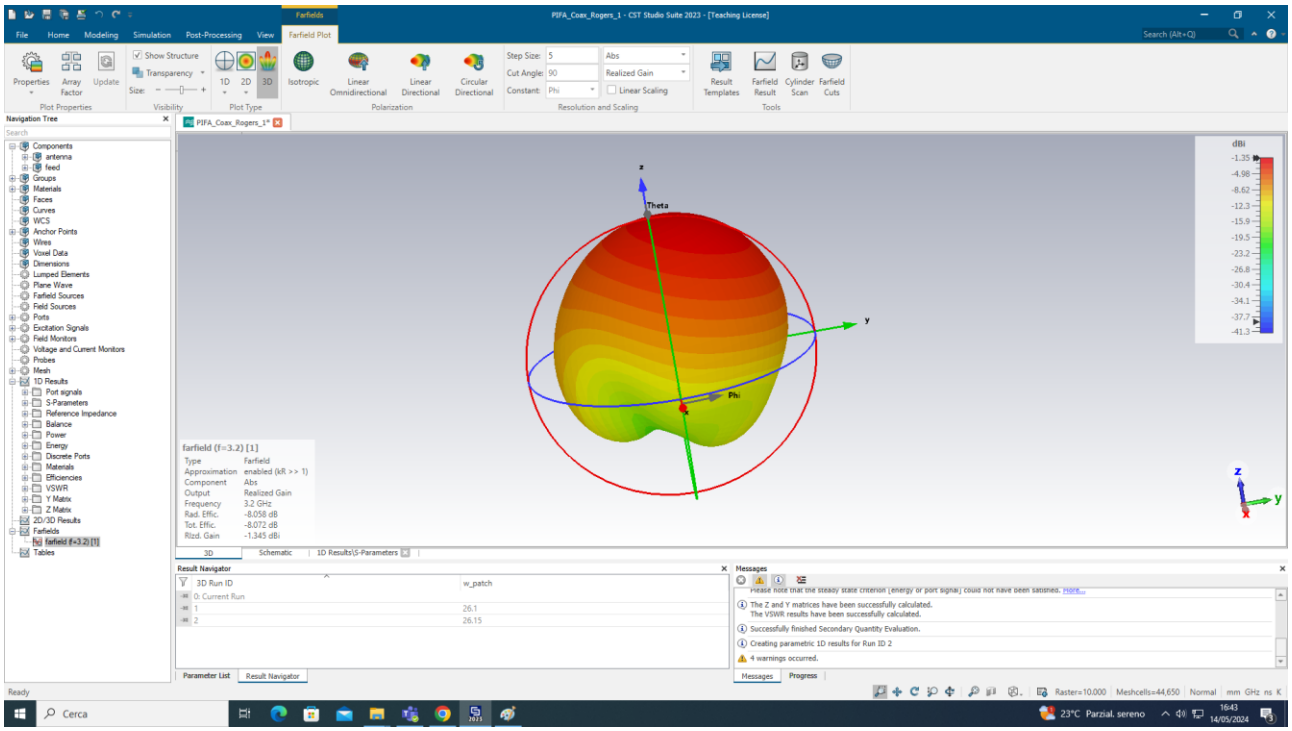



Directivity, constant Theta=90
Directivity, constant Theta...
0
30
330
60
300
90
270
120
240
150
210
180
-8
-6
-4
-2
Phi / deg


f=3.2
f=3.2 (w_patch=26.15)
0
30
330
60
300
90
270
120
240
150
210
180
-20
-15
-10
-5
Theta / deg

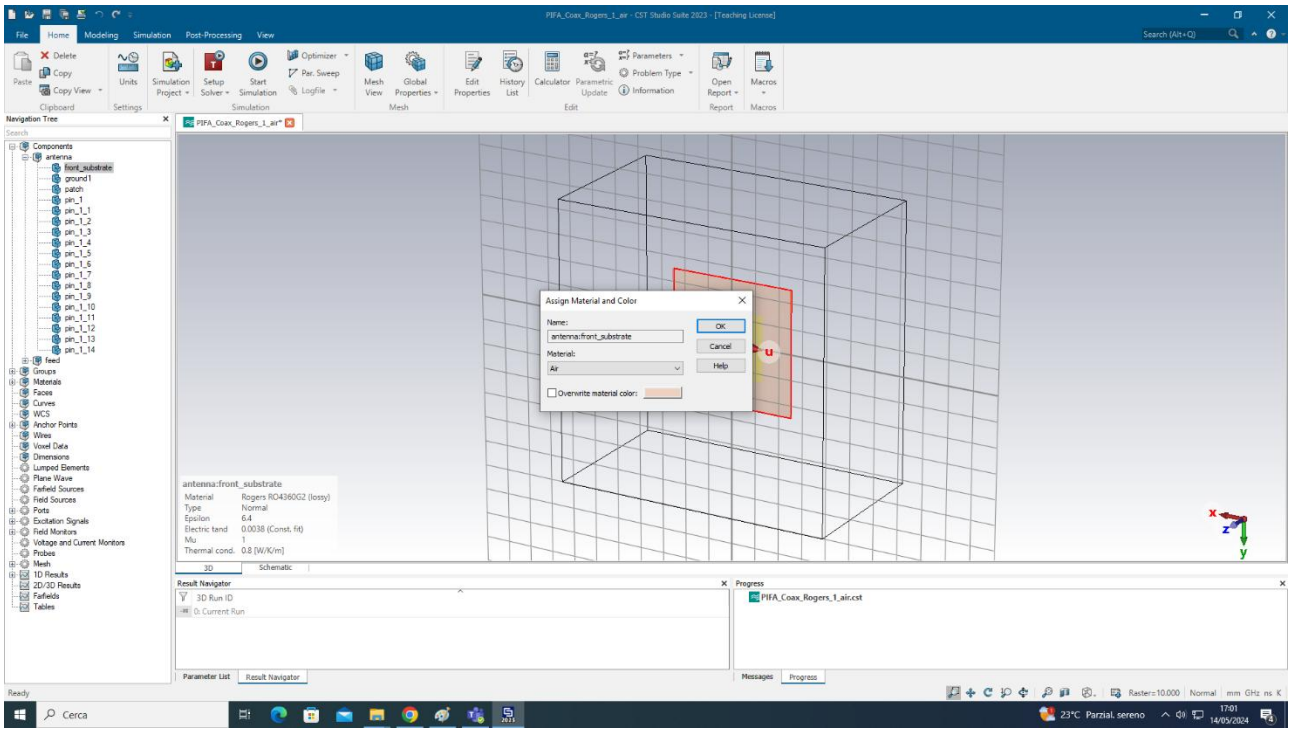

Farfield Realized Gain Abs (Phi=90)
farfield (f=3.2) [1]
Phi= 90
Phi=270
Theta / deg vs. dBi
Frequency = 3.2 GHz
Main lobe magnitude = -1.34 dBi
Main lobe direction = 17.0 deg.
Angular width (3 dB) = 85.5 deg.
Side lobe level = -10.4 dB


Farfield 'farfield (f=3.2) [1]'
dBi
farfield (f=3.2) [1]

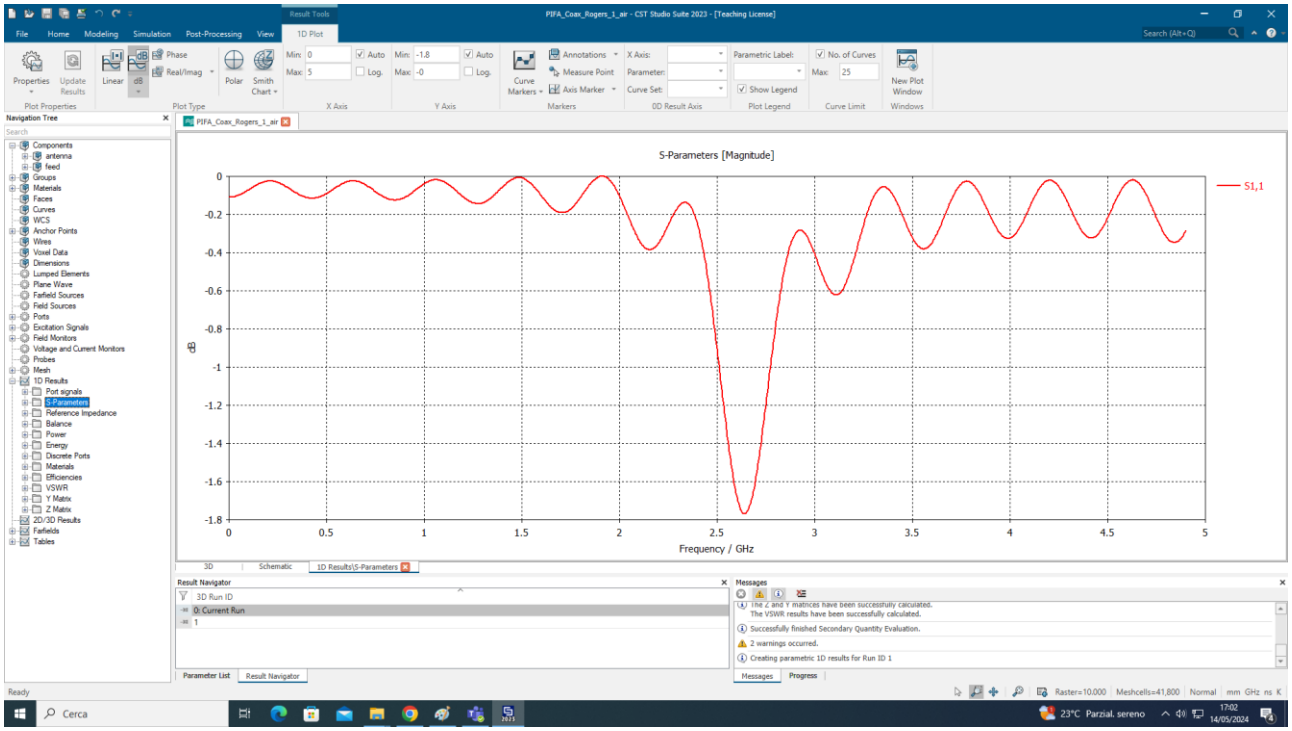


### 3. Retuning with Air as Substrate

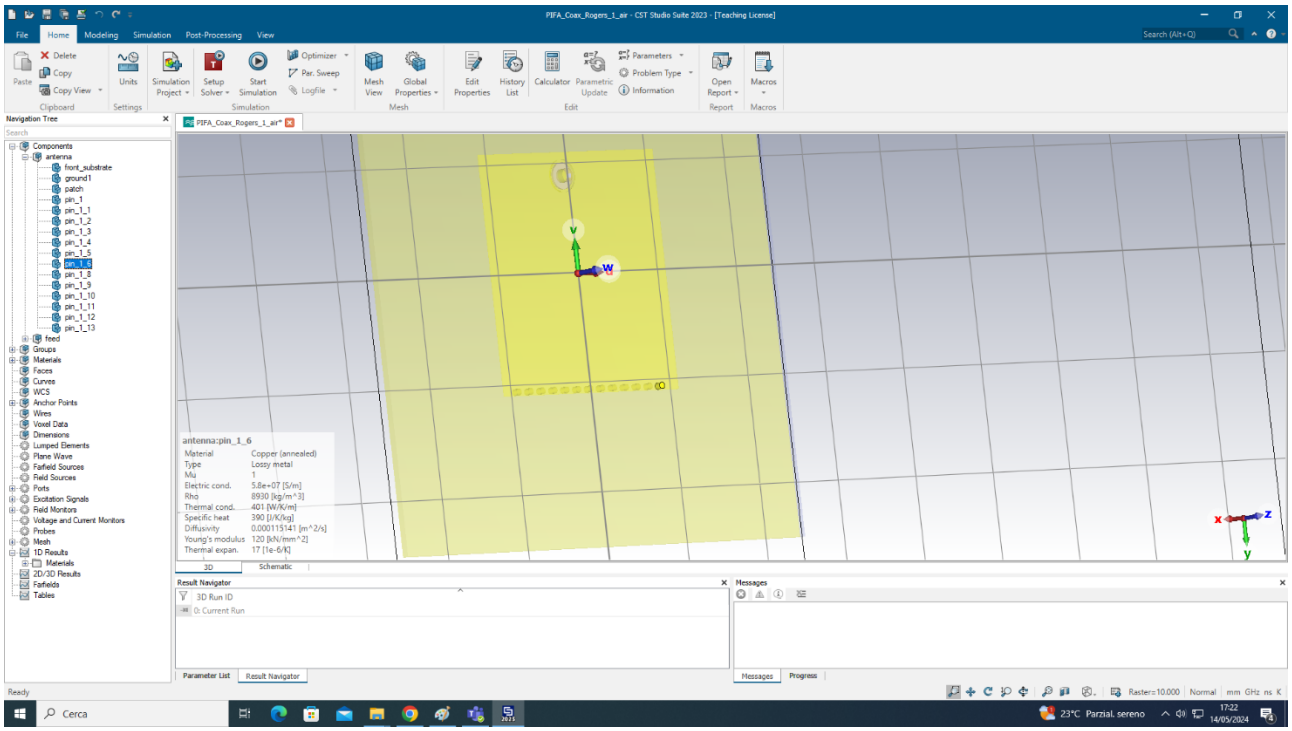
The next step was to replace the **Rogers substrate** with **air** and analyze the effect on antenna performance, especially efficiency.



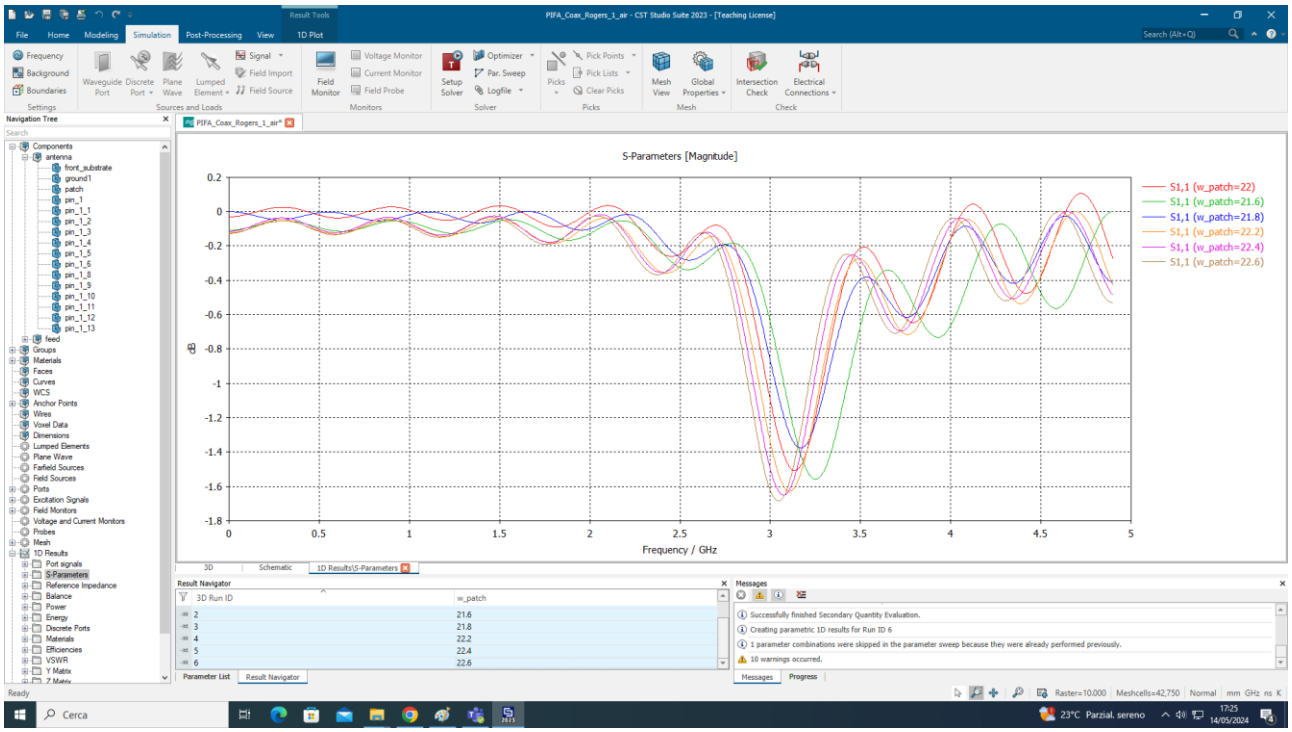
This required changing the material properties of the substrate to “air” in CST. A new simulation was then carried out without applying any further parameter modifications.



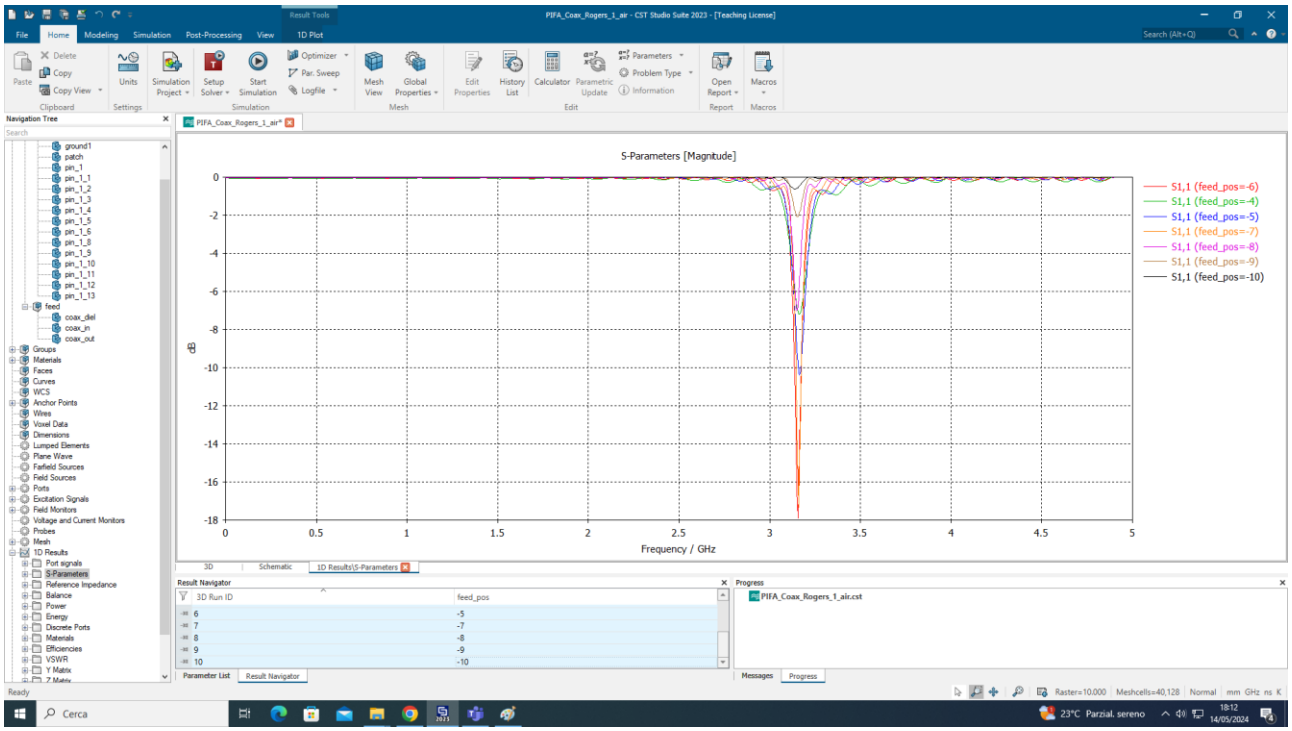

It is evident that the antenna no longer provides optimal performance. Therefore, a new optimization process was necessary. Since the tuning procedure through parameter sweep tends to reduce the patch width, the next step involved **removing some pins**, which significantly affected the antenna characteristics.



In particular, two outer pins were removed, followed by a width parameter sweep.

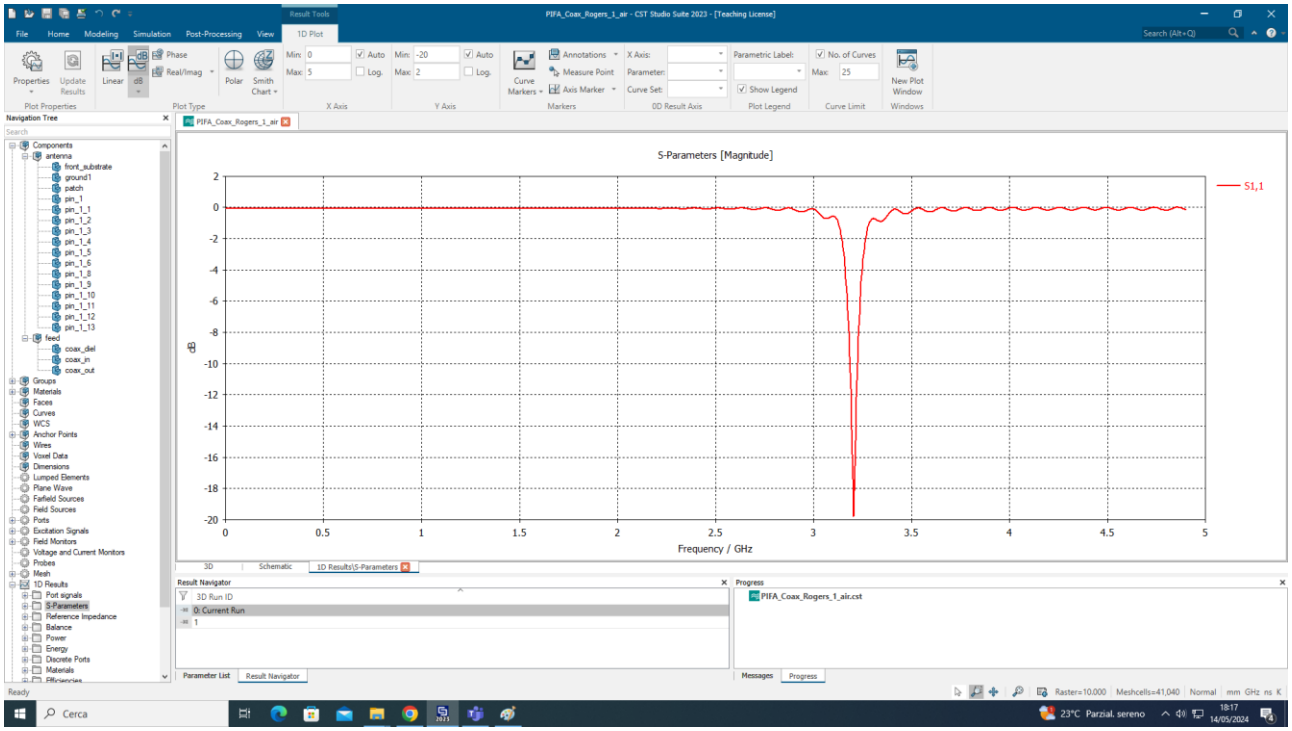



An approximate patch width of **21.8 mm** allowed the antenna to resonate at 3.2 GHz. However, the attenuation was only **–1.6 dB**, which is not acceptable. To improve this, the feeding position was modified, and another sweep was performed on this parameter.




A significant improvement in antenna performance was observed after adjusting the feeding position. After several iterations, the optimal parameters were found to be:

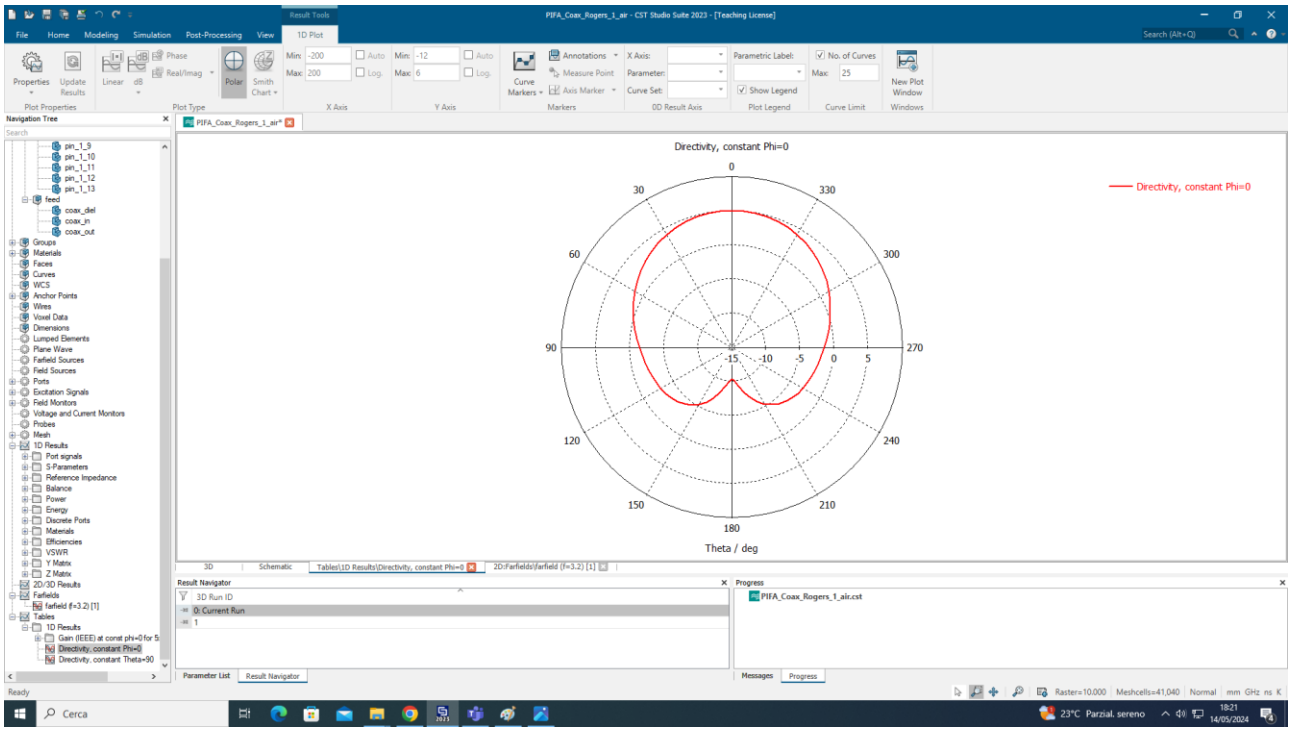
- Patch width: **21.3 mm**
- Feeding position: **–6 mm** (with respect to center)
- Removal of two external pins

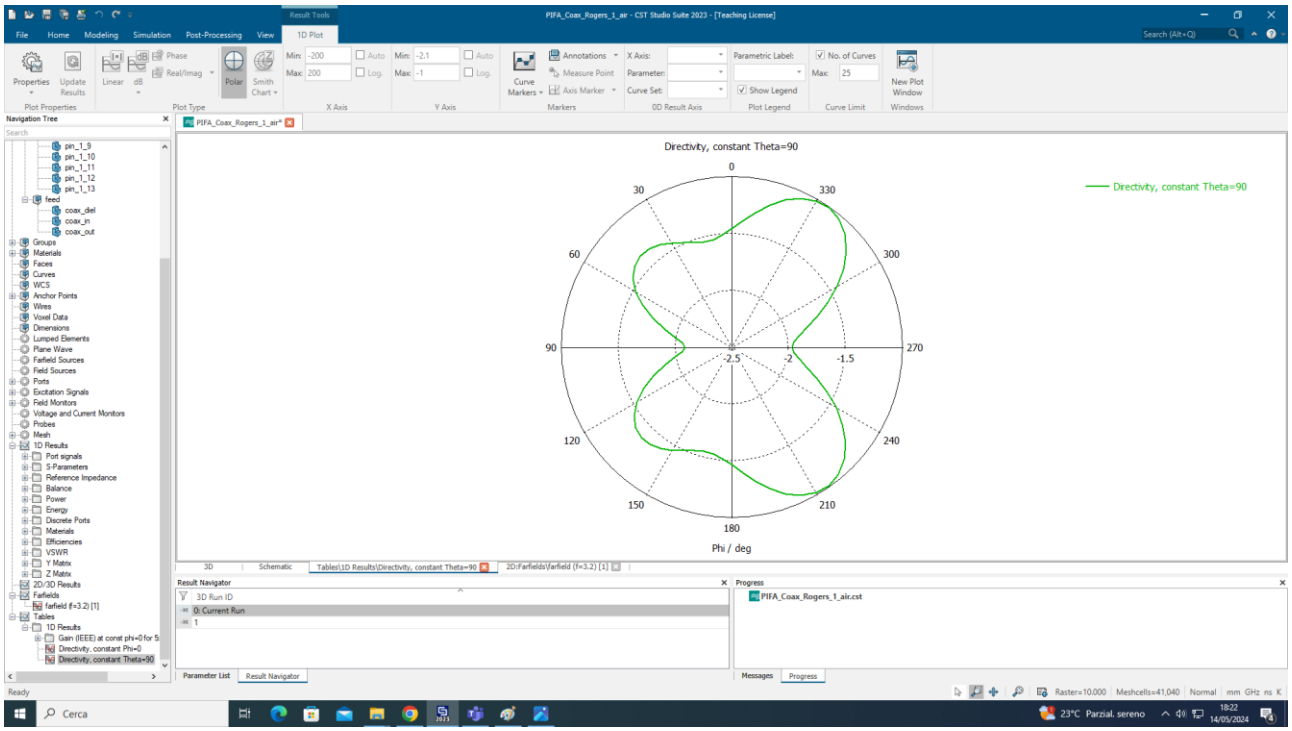


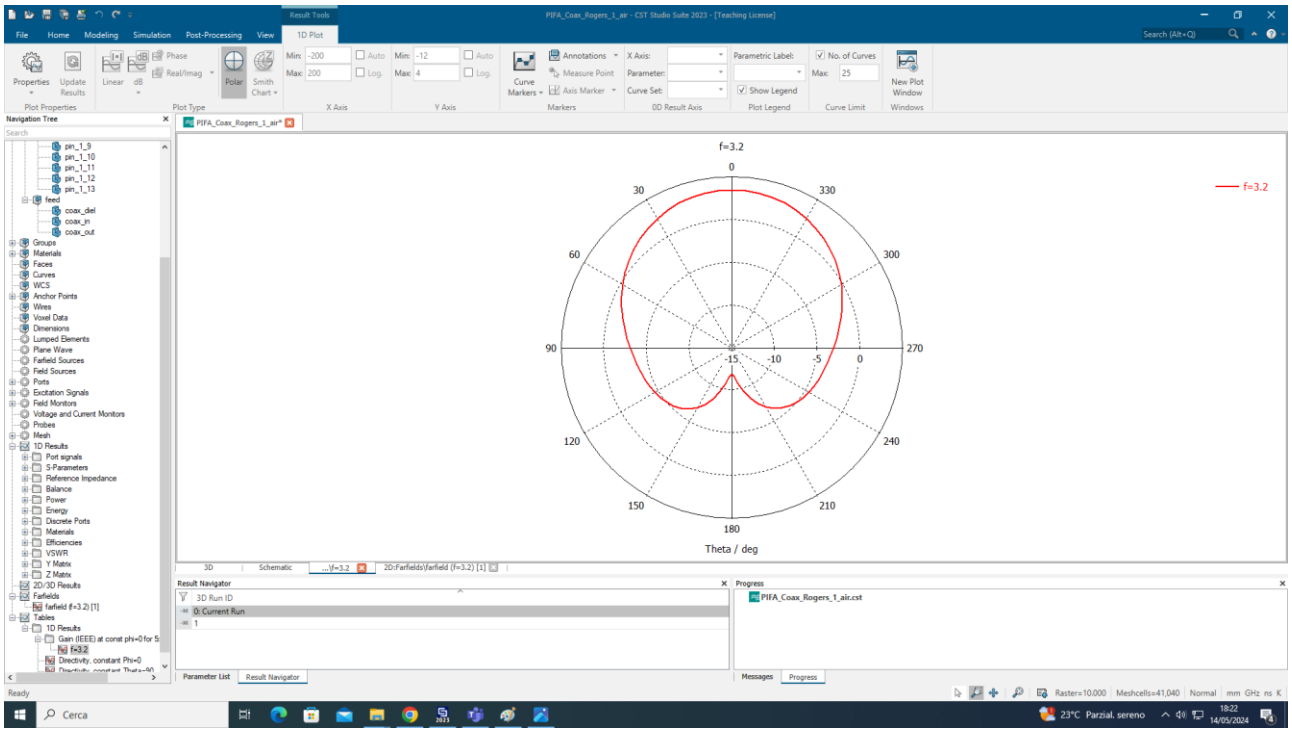
The resulting antenna was tuned to 3.2 GHz with an attenuation of about **–20 dB**.

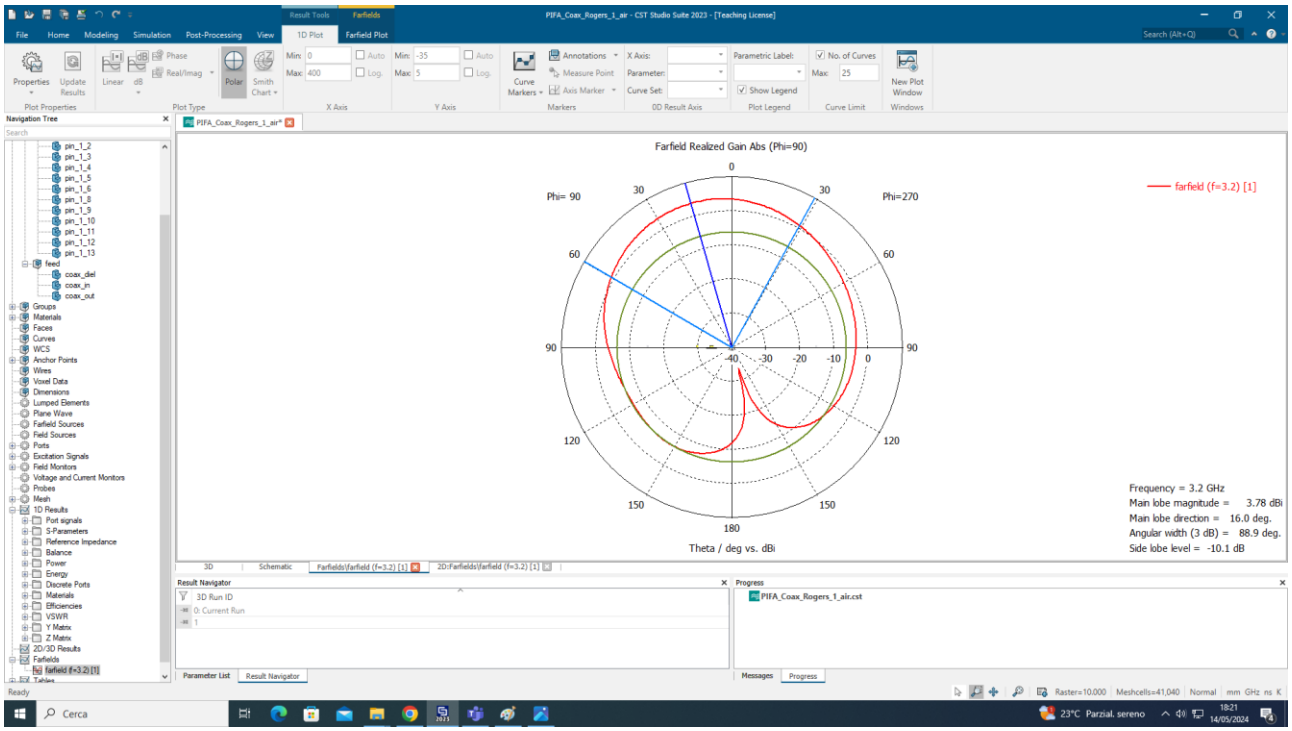
The following results were extracted:

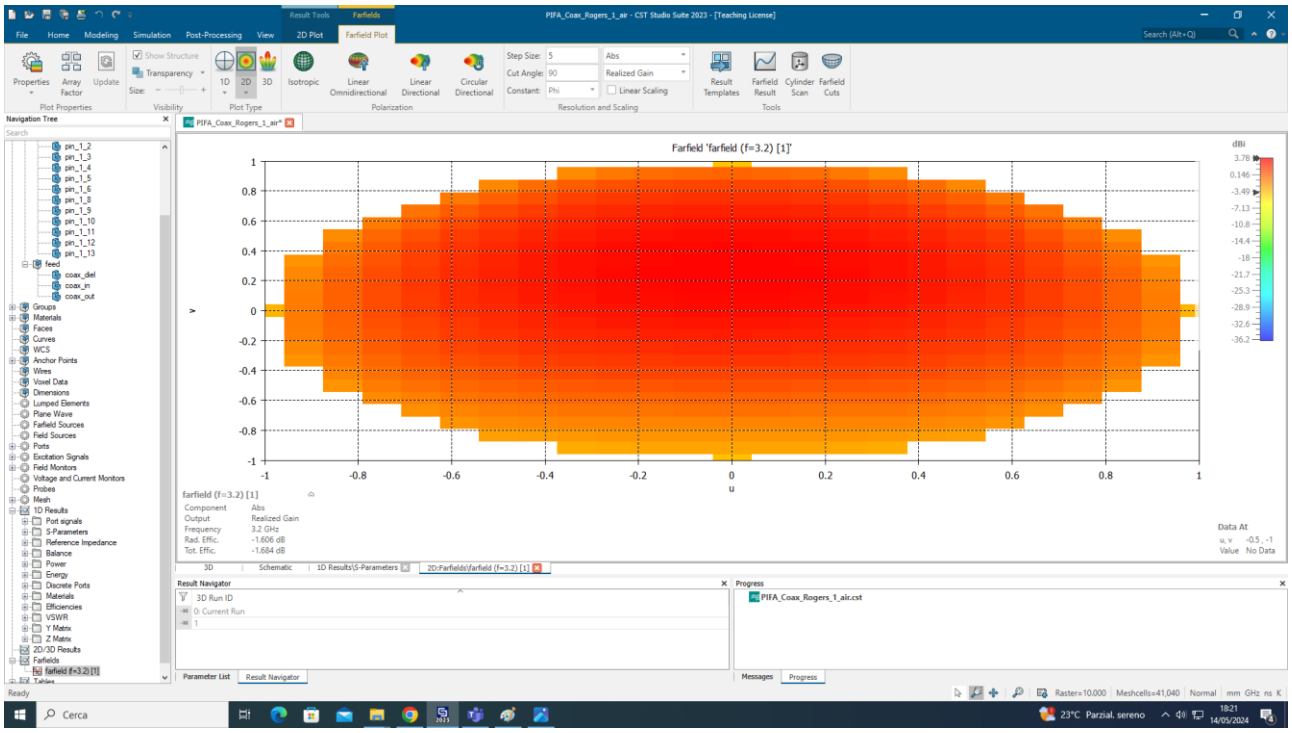
- Directivity
- IEEE Gain
- Realized Gain
- 2D radiation diagrams
- Far-field 3D plots

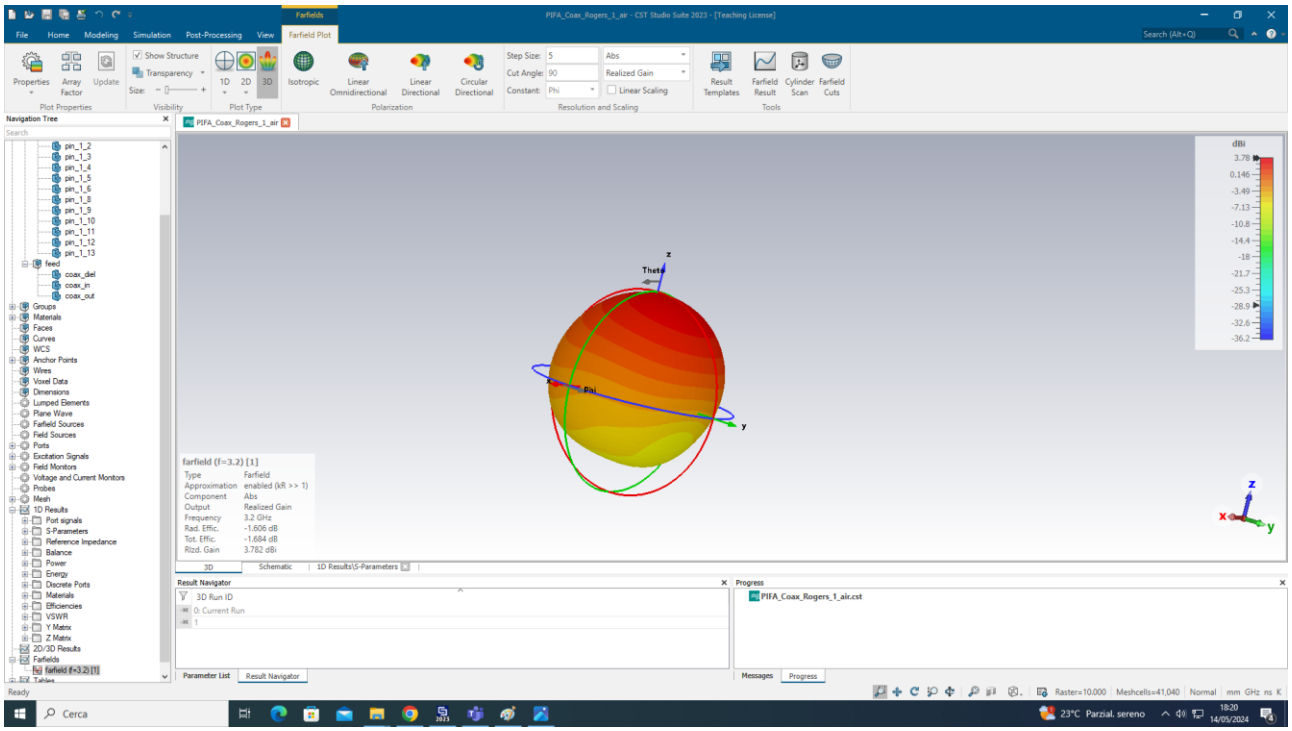



PIFA_Coax_Rogers_1_air - CST Studio Suite 2023 - [Teaching License]
Directivity, constant Theta=90
Directivity, constant Theta=90
0
30
330
60
300
90
270
120
240
150
210
180
-2.5
-2
-1.5
Phi / deg


PIFA_Coax_Rogers_1_air - CST Studio Suite 2023 - [Teaching License]
f=3.2
f=3.2
0
30
330
60
300
90
270
120
240
150
210
180
-15
-10
-5
0
Theta / deg

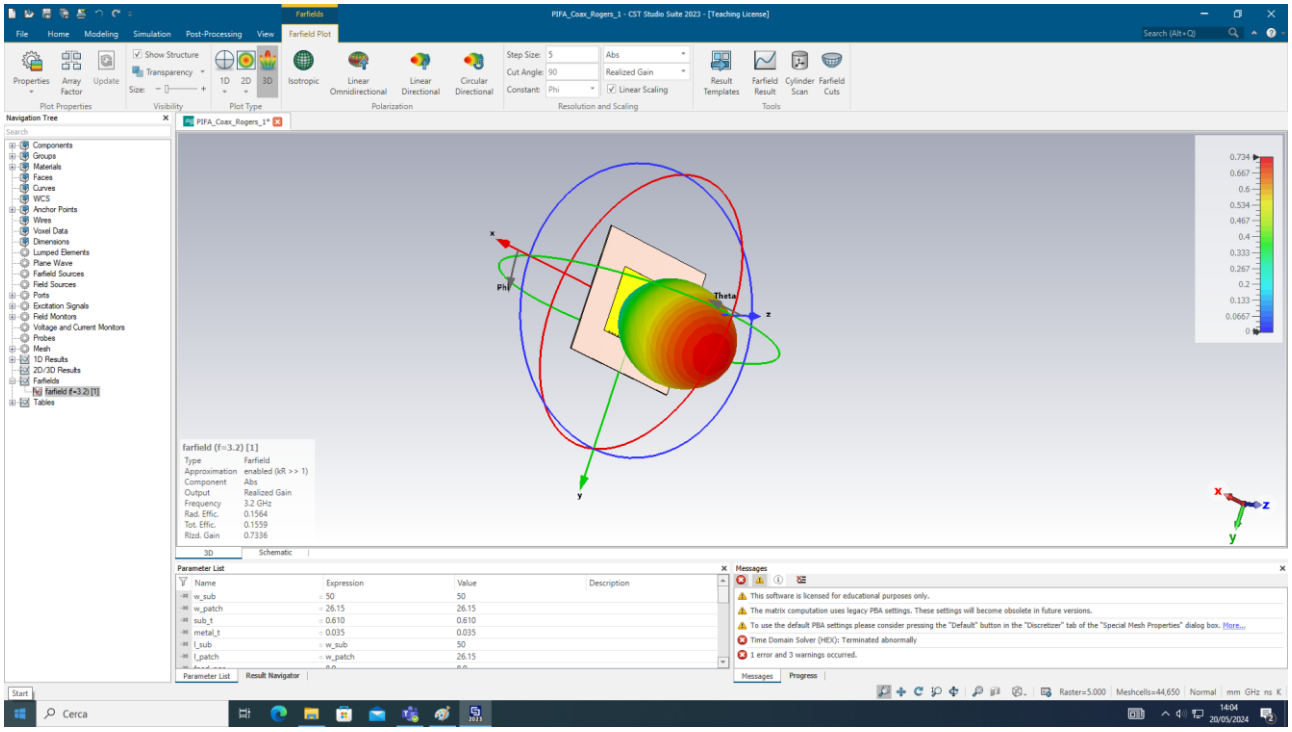

PIFA_Coax_Rogers_1_air - CST Studio Suite 2023 - [Teaching License]
Farfield Realized Gain Abs (Phi=90)
Phi= 90
Phi=270
farfield (f=3.2) [1]
Theta / deg vs. dBi
Frequency = 3.2 GHz
Main lobe magnitude = 3.78 dBi
Main lobe direction = 16.0 deg.
Angular width (3 dB) = 88.9 deg.
Side lobe level = -10.1 dB

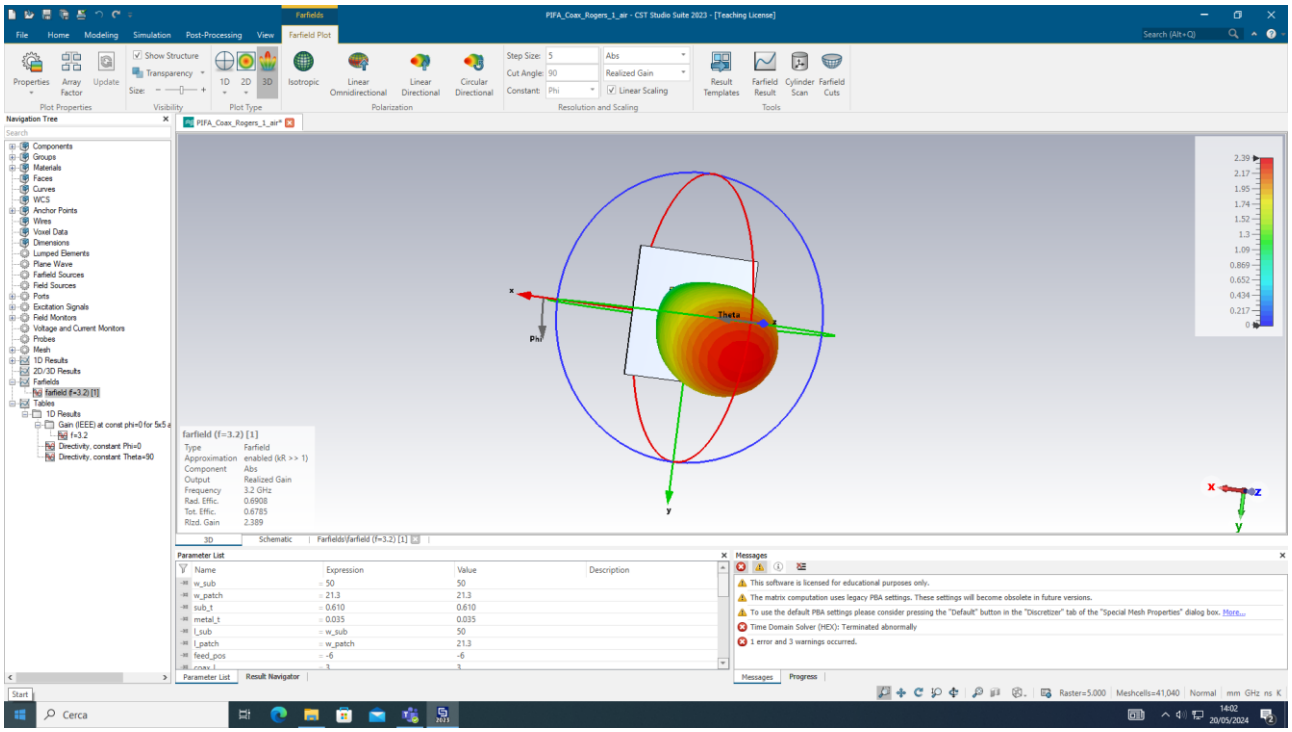

PIFA_Coax_Rogers_1_air - CST Studio Suite 2023 - [Teaching License]
Farfield 'farfield (f=3.2) [1]'
farfield (f=3.2) [1]




## 4. Efficiency Comparison

The analysis of the **far-field plot in linear scale** allows evaluation of antenna efficiency.






The total efficiency is:

- With Rogers substrate: **15.59%**
- With air substrate: **67.85%**

The improved efficiency with air is due to its lower **relative permittivity ($\varepsilon_r$)** compared to Rogers, which reduces losses and improves overall performance.

### 5. Conclusion

This laboratory activity provided hands-on experience with **antenna tuning in CST**. Starting from a pre-defined PIFA model, the antenna was successfully re-tuned to the target frequency of 3.2 GHz using **parameter sweeps** for geometry and feeding optimization.

The comparison between Rogers and air substrates highlighted the strong impact of material choice on antenna efficiency, showing that air can significantly enhance performance.