American University of Sharjah
Department of Electrical Engineering

ELE 454 Antennas and Wave Propagation
Spring 2022

Course Project

Group members:

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Introduction

The purpose of this project is to design and build an antenna based on our knowledge gained from the course so far. Our Antenna specifications are the following: 1- Must operate at 3GHz with an available bandwidth of around 10% of the operating frequency. 2- A directivity of greater than 15 dB. 3- A gain of greater than 12 dB. 4- Cost of material to be no more than 100 AED. 5- Design the parameters our antennas using HFss and simulate our design using Ansys Electronics. In our project we will show simulations results and measurements of both horn and helical antenna.

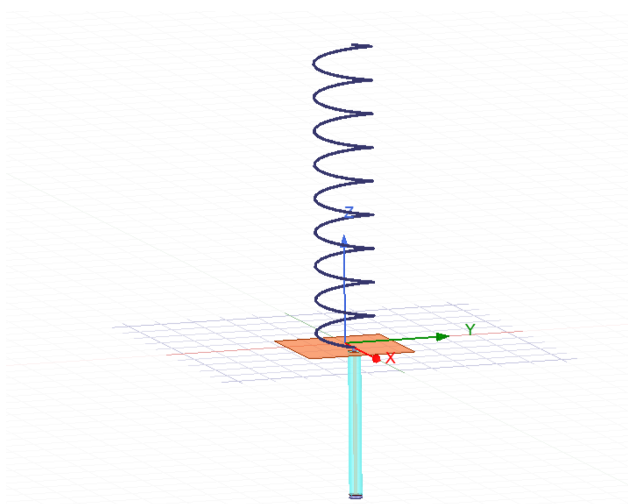
Methodology

The first step was to extract the design parameters through calculating them using a simple online calculator for both Helical and Horn antennas. All antennas were designed to operate at 3GHz. Then, Ansys Electronics was used to simulate the designed antennas and view how they are expected to perform. The simulation results are listed below.

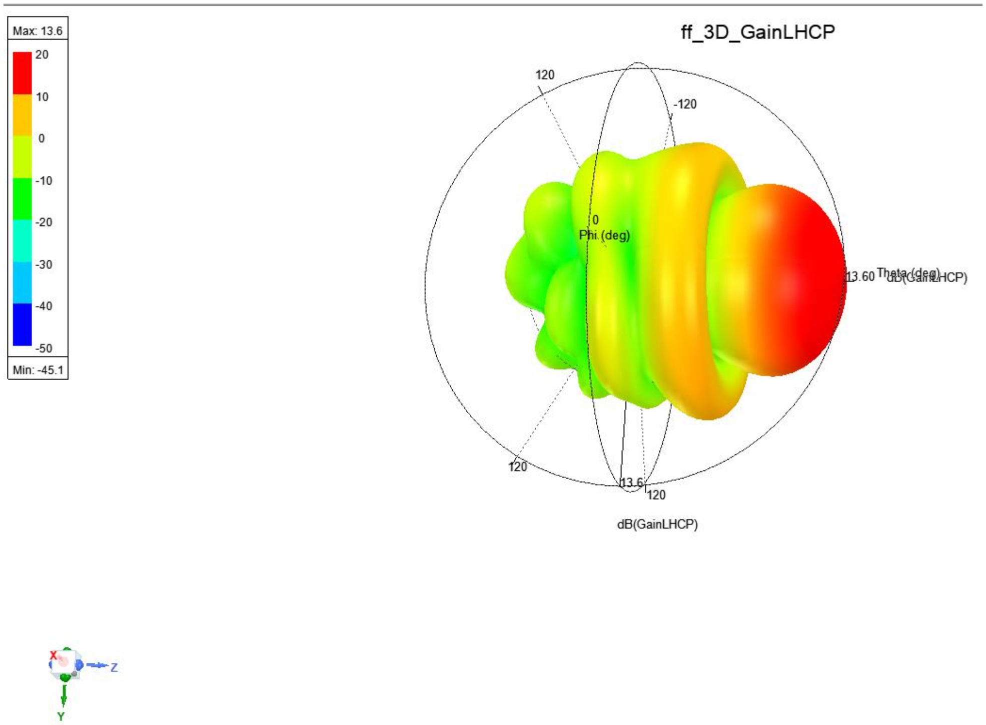
I. Helical Antenna:

The maximum gain at 3GHz was 13.6dB with a HPBW of 33 degrees.

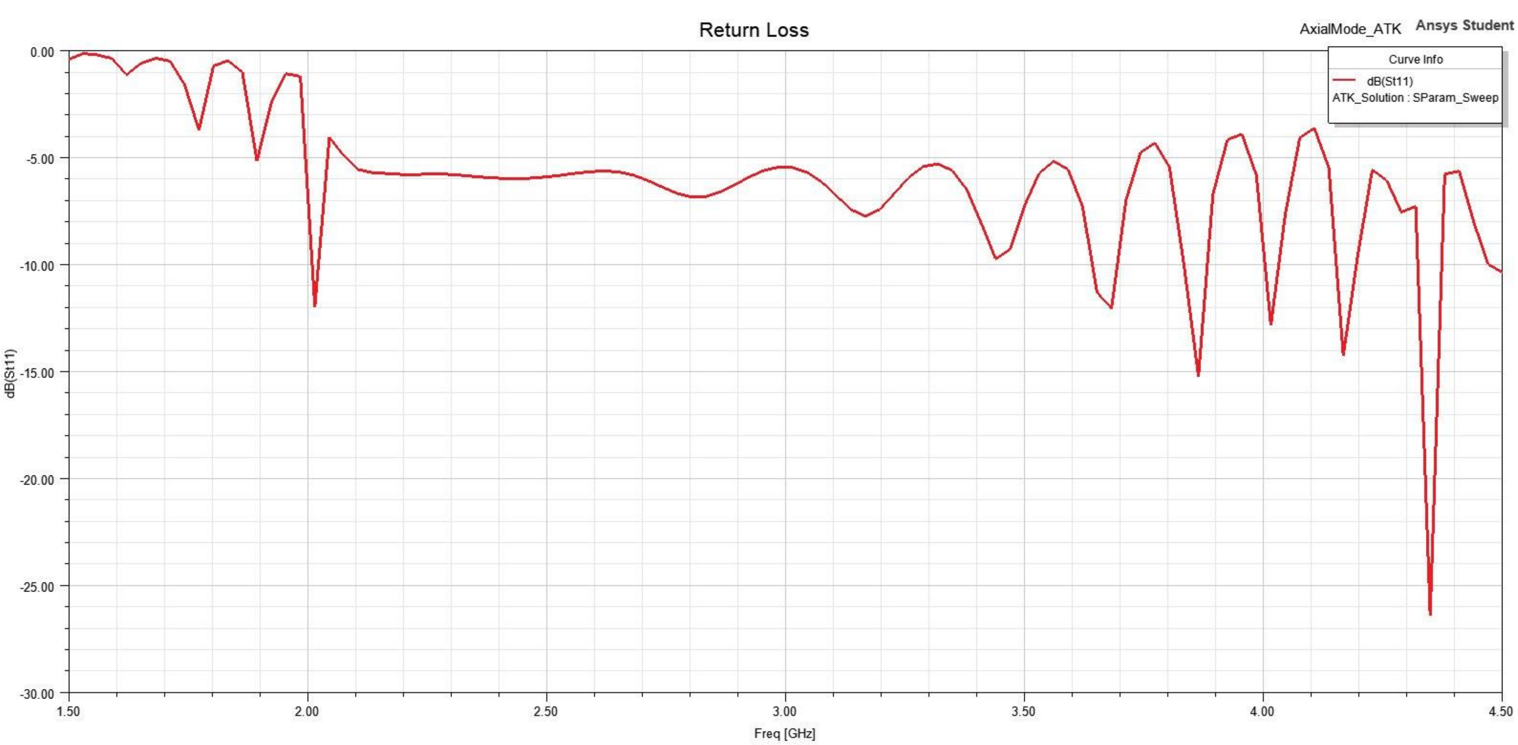
Model:



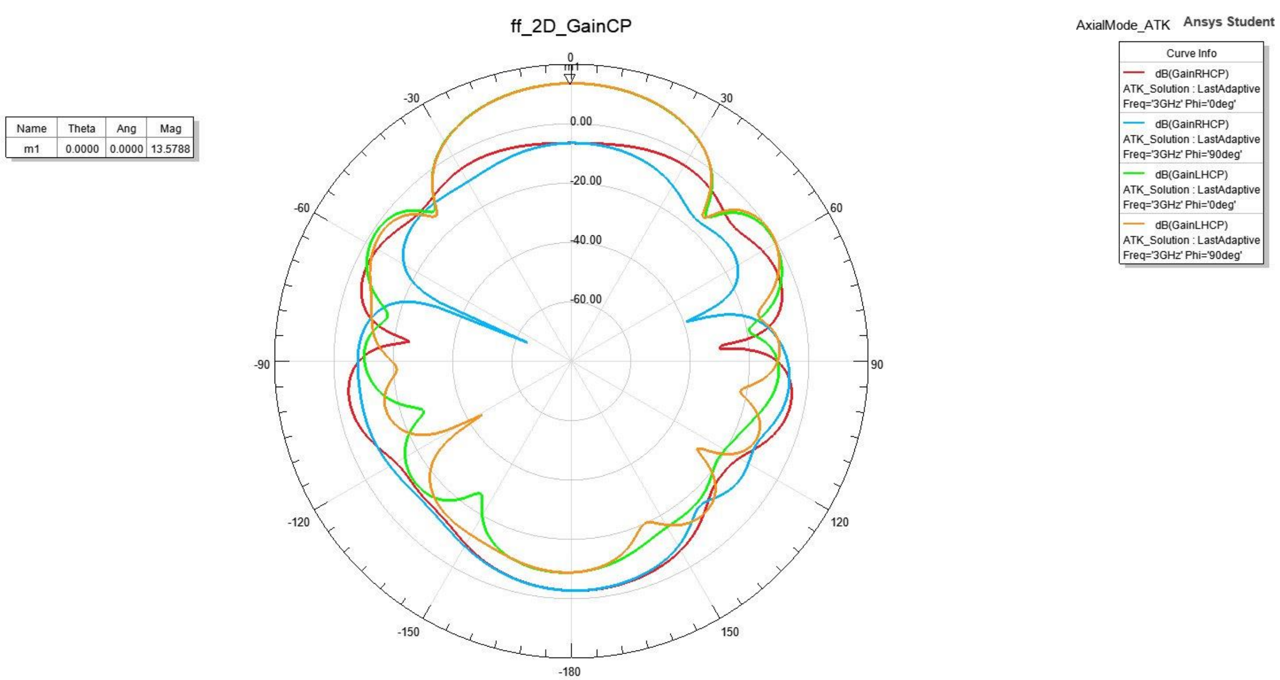
3D Gain Plot :



Return loss (S11):



2D gain plot:


ff_2D_GainCP
AxialMode_ATK
Ansys Student
Name | Theta | Ang | Mag
m1 | 0.0000 | 0.0000 | 13.5788
Curve Info
dB(GainRHCP)
ATK_Solution : LastAdaptive
Freq='3GHz' Phi='0deg'
dB(GainRHCP)
ATK_Solution : LastAdaptive
Freq='3GHz' Phi='90deg'
dB(GainLHCP)
ATK_Solution : LastAdaptive
Freq='3GHz' Phi='0deg'
dB(GainLHCP)
ATK_Solution : LastAdaptive
Freq='3GHz' Phi='90deg'
0
m1
-30
30
-60
60
-90
90
-120
120
-150
150
-180
0.00
-20.00
-40.00
-60.00

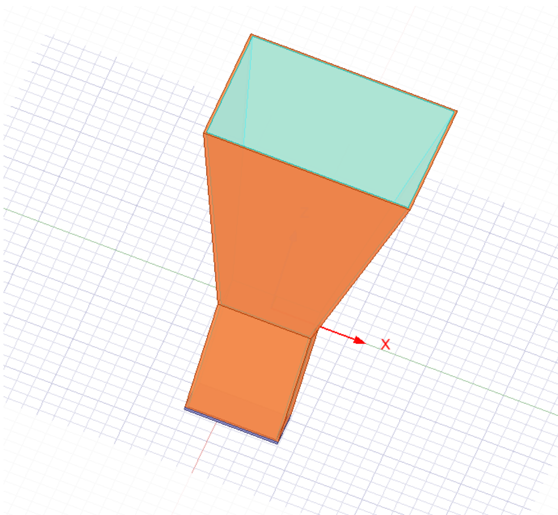
Parameters:

Name	Value	Unit	"Evaluated Value"	Type
"--Antenna Dimensions"				Design
Helix_Diameter	3.43	cm	3.43cm	Design
Helix_Spacing	2	cm	2cm	Design
Wire_Diameter	0.1291	cm	0.1291cm	Design
NumberOfTurns	9		9	Design
"--Feed Dimensions"				Design
coax_inner_rad	0.116	cm	0.116cm	Design
coax_outer_rad	0.388	cm	0.388cm	Design
feedLength	8.5	cm	8.5cm	Design
Pin_Length	0.141	cm	0.141cm	Design
Pin_Diameter	0.231	cm	0.231cm	Design
"--Ground Plane Dimensions"				Design
groundX	6.5	cm	6.5cm	Design
groundY	6.5	cm	6.5cm	Design
Name	Value	Unit	"Evaluated Value"	Type
"--Antenna Dimensions"				Design
Helix_Diameter	3.43	cm	3.43cm	Design
Helix_Spacing	2	cm	2cm	Design
Wire_Diameter	0.1291	cm	0.1291cm	Design
NumberOfTurns	9		9	Design
"--Feed Dimensions"				Design

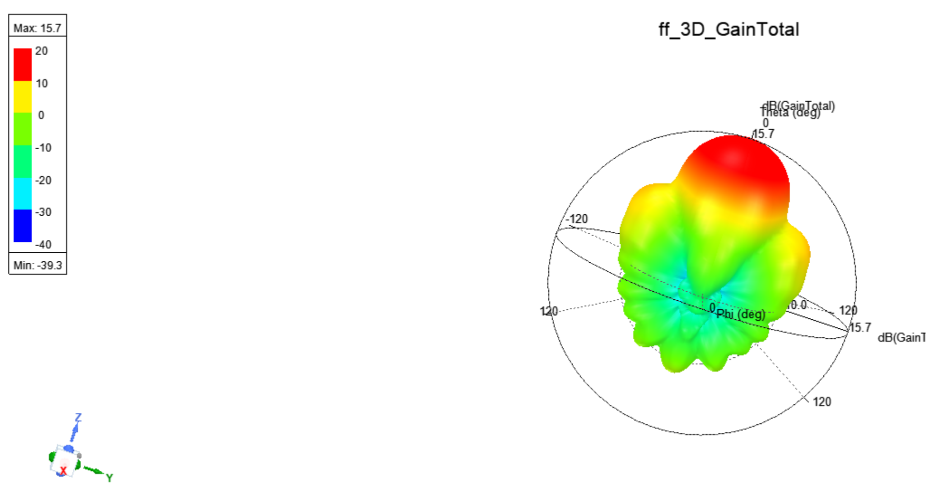
II. Horn V1 (black):

The simulation results in a max gain of 15.65 dB and a HPBW of 29 degrees at 3GHz

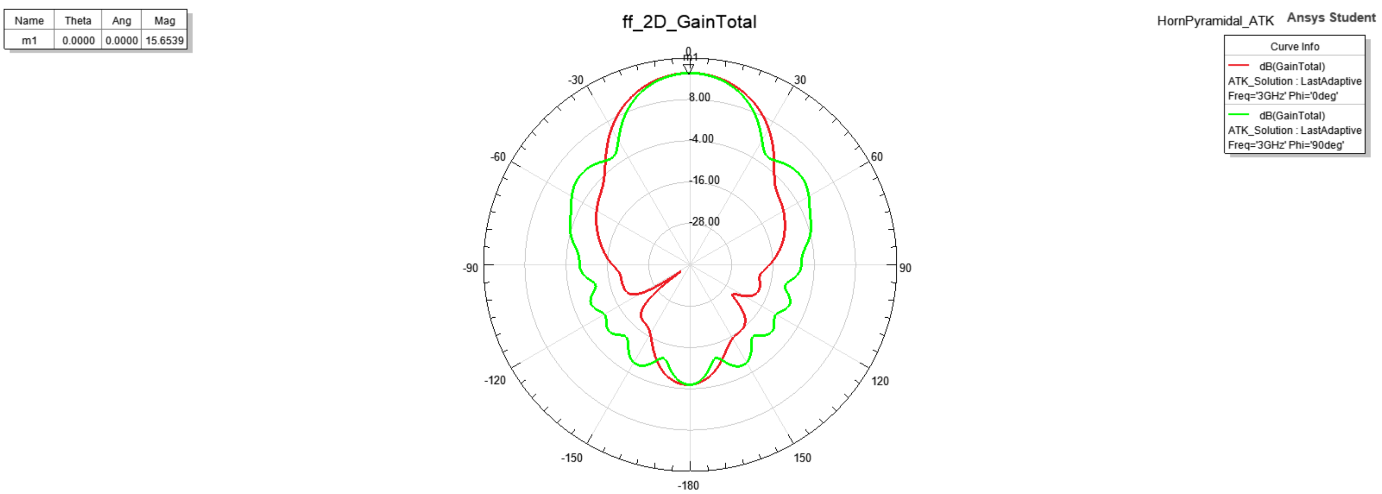
Model:



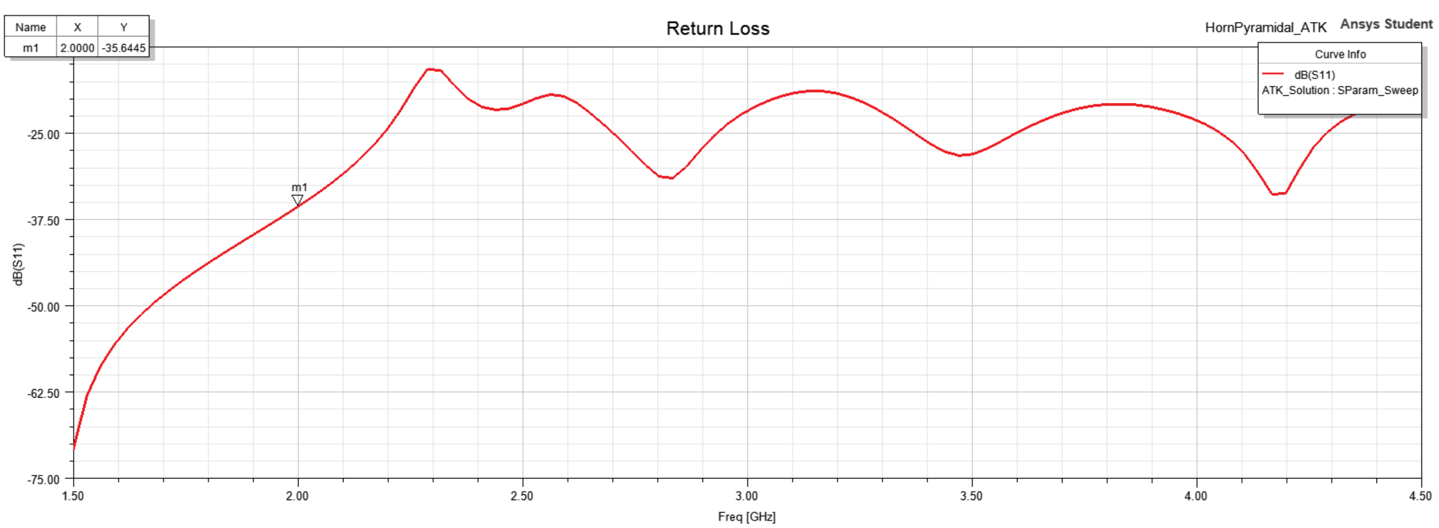
3D Gain Plot:



2D Gain Plot:



Return loss (S11):



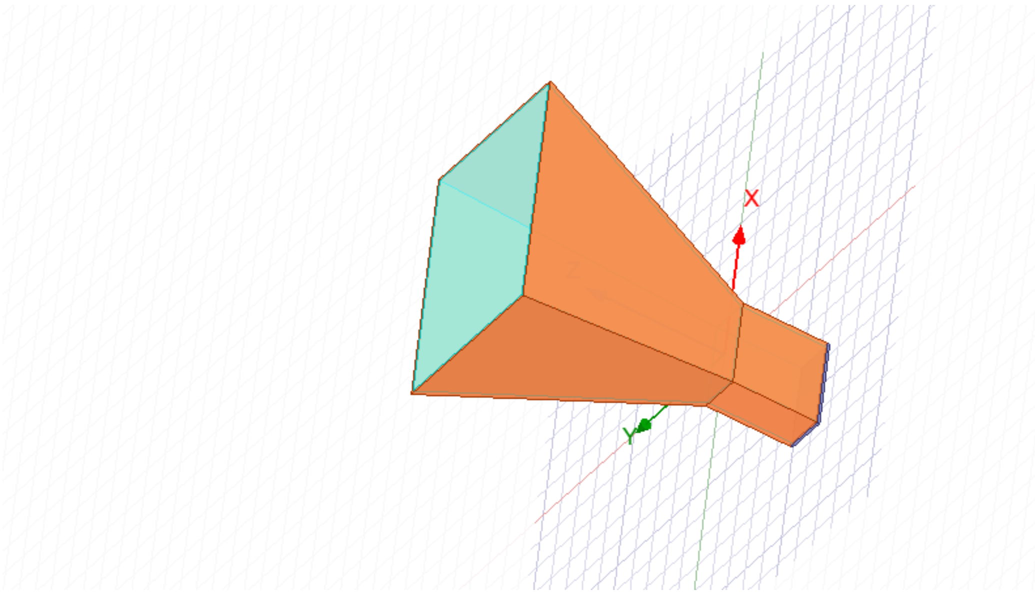
Parameters:

Name	Value	Unit	"Evaluated Value"	Type	Name	Value	Unit	"Evaluated Value"
"--Antenna Dimensions"				Design	"--Antenna Dimensions"			
Horn_a	200	mm	200mm	Design	Horn_a	200	mm	200mm
Horn_b	175	mm	175mm	Design	Horn_b	175	mm	175mm
Horn_length	188	mm	188mm	Design	Horn_length	188	mm	188mm
"--Standard Waveguide"				Design	"--Standard Waveguide"			
WG_a	2.84	in	2.84in	Design	WG_a	2.84	in	2.84in
WG_b	1.34	in	1.34in	Design	WG_b	1.34	in	1.34in
WG_Wall_Thickness	0.08	in	0.08in	Design	WG_Wall_Thickness	0.08	in	0.08in
WG_length	112.6	mm	112.6mm	Design	WG_length	112.6	mm	112.6mm

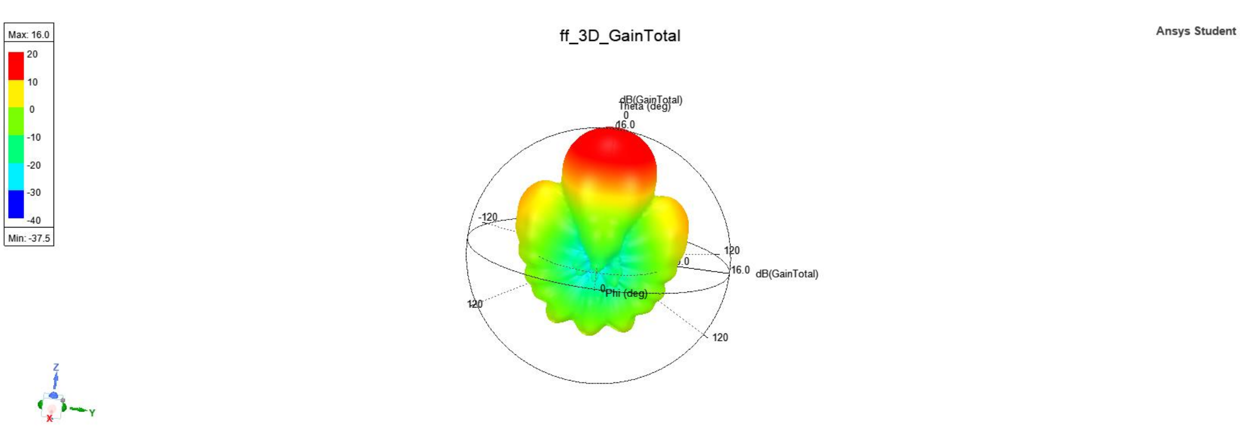
III. Horn V2 (red):

The second horn antenna examined has a gain of 15.96dB and a HPBW of 31 degrees at 3GHz.

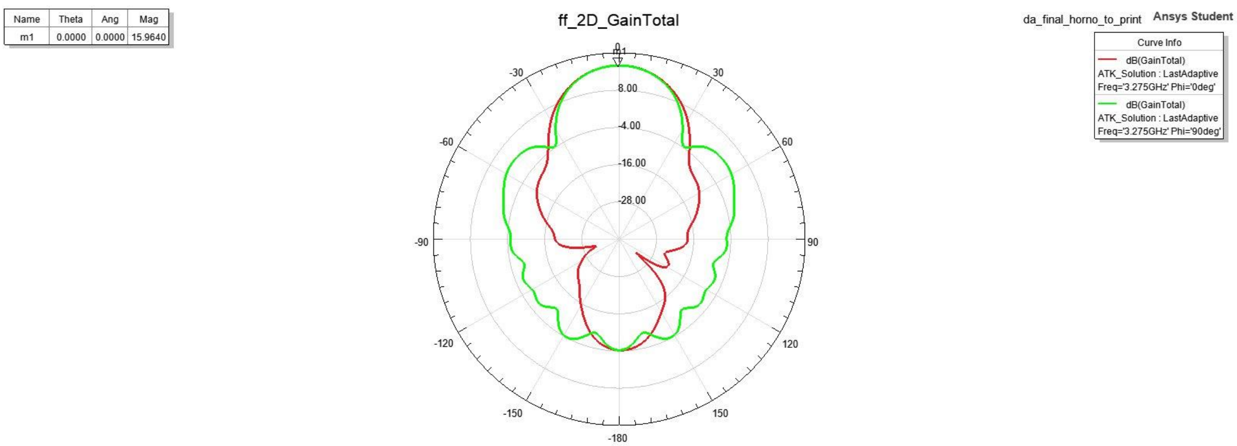
Model:



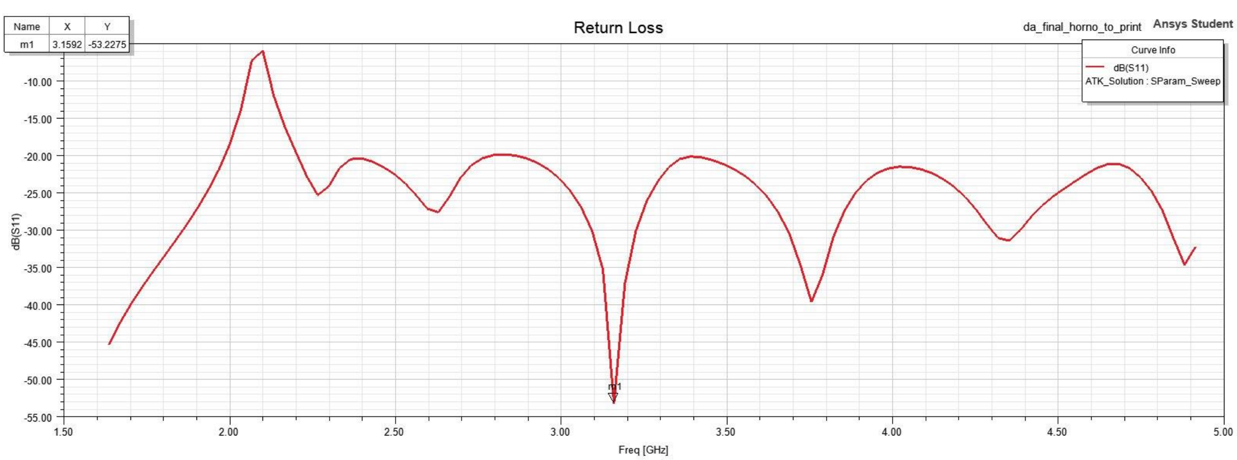
3D Gain Plot:



2D Gain Plot:



Return loss (S11):



Parameters:

Name	Value	Unit	"Evaluated Value"	Type	Name	Value	Unit	"Evaluated Value"
"--Antenna Dimensions"				Design	"--Antenna Dimensions"			
Horn_a	8	in	8in	Design	Horn_a	8	in	8in
Horn_b	6	in	6in	Design	Horn_b	6	in	6in
Horn_length	220	mm	220mm	Design	Horn_length	220	mm	220mm
"--Standard Waveguide"				Design	"--Standard Waveguide"			
WG_a	2.84	in	2.84in	Design	WG_a	2.84	in	2.84in
WG_b	1.34	in	1.34in	Design	WG_b	1.34	in	1.34in
WG_Wall_Thickness	0.08	in	0.08in	Design	WG_Wall_Thickness	0.08	in	0.08in
WG_length	3	in	3in	Design	WG_length	3	in	3in

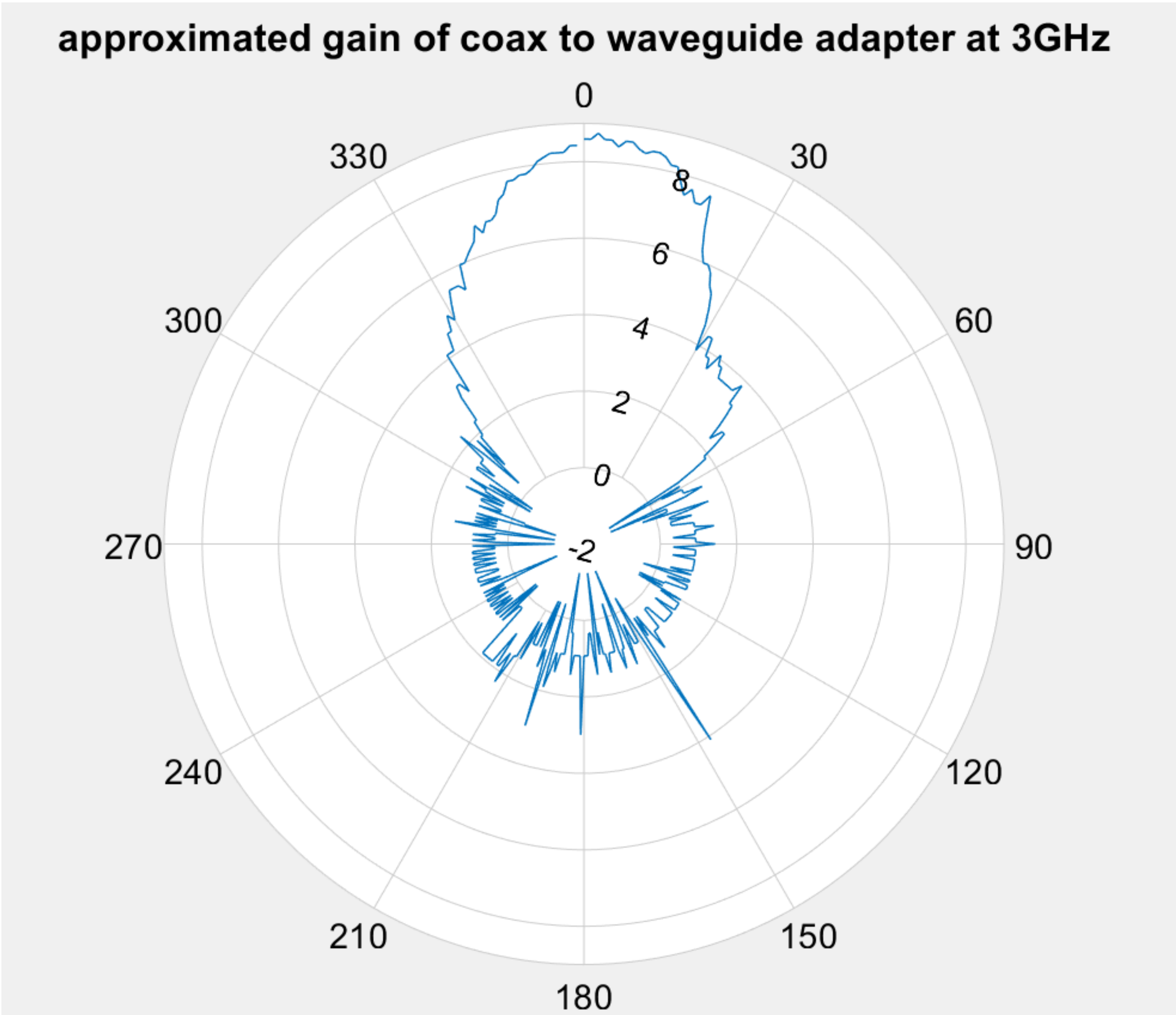
Measurement Results

The gain of the antenna can be found using the two antennas method:

$$(G_{0t})_{\mathrm{dB}} + (G_{0r})_{\mathrm{dB}} = 20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\left(\frac{P_r}{P_t}\right)$$

The measurements on all antennas were done with a separation distance of approximately 1.6m. the transmitting antenna used was a wideband ridged horn antenna due to its known Gain. The transmitting antenna has a gain of 11.5dB at 3GHz, and a gain of 10.6dB at 2.6GHz. the transmitting antenna was connected to a function generator. The transmitted signal had a power level of 7dbm, and it was amplitude modulated using a 1KHz square wave with a 100% modulation index. All antennas were attached on 360 degrees rotation angle antenna trainer, and only E plane measurements were performed due to the setup limitations. A Vector network Analyzer was used to measure the reflection coefficient of each antenna to examine their respective bandwidths.

Coaxial to waveguide adapter specifications:

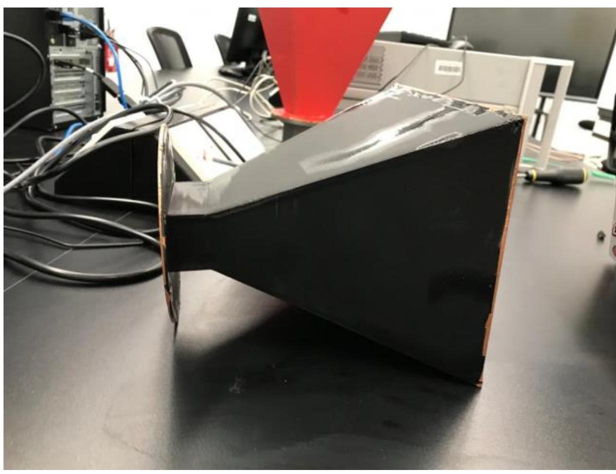


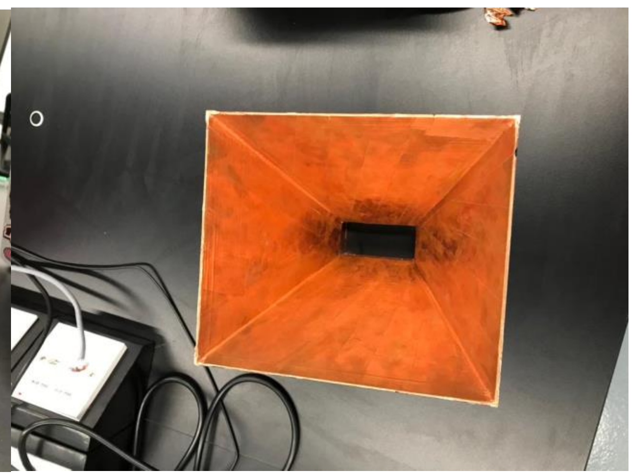
The adapter has a HPBW of 51 degrees, a max gain of 8.75dB, and an (sidelobe level) SLL of -4.65dB. The SLL is difference in gain between the maximum sidelobe and the main lobe.

Antenna design:

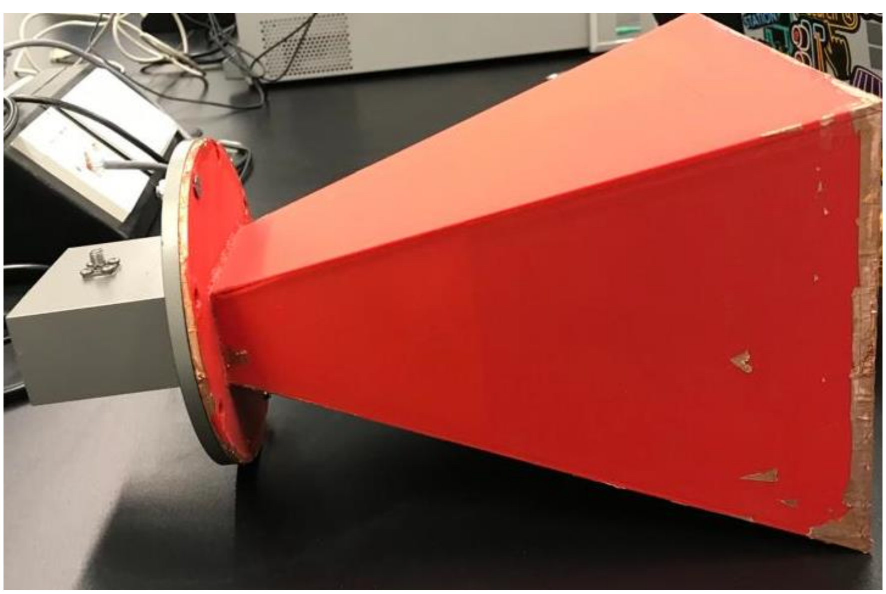
We 3D printed both of our horn antennas to which we coated with epoxy. Additionally, we covered the insides of our antenna with conductive tape. As for our helical antenna, we 3D printed a supporting structure such that we can achieve constant spacings for the antenna windings and contain its shape.

I. Black horn antenna:

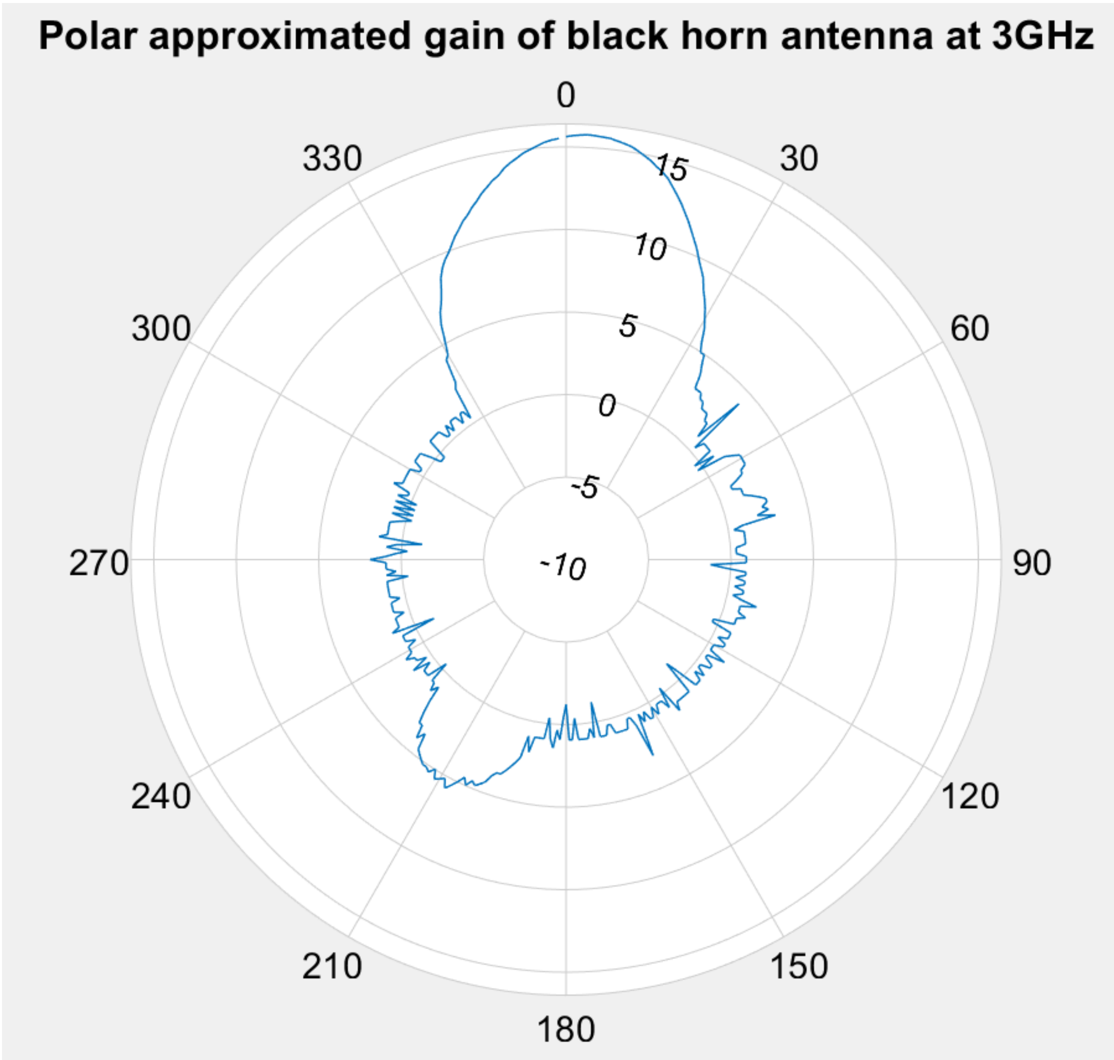




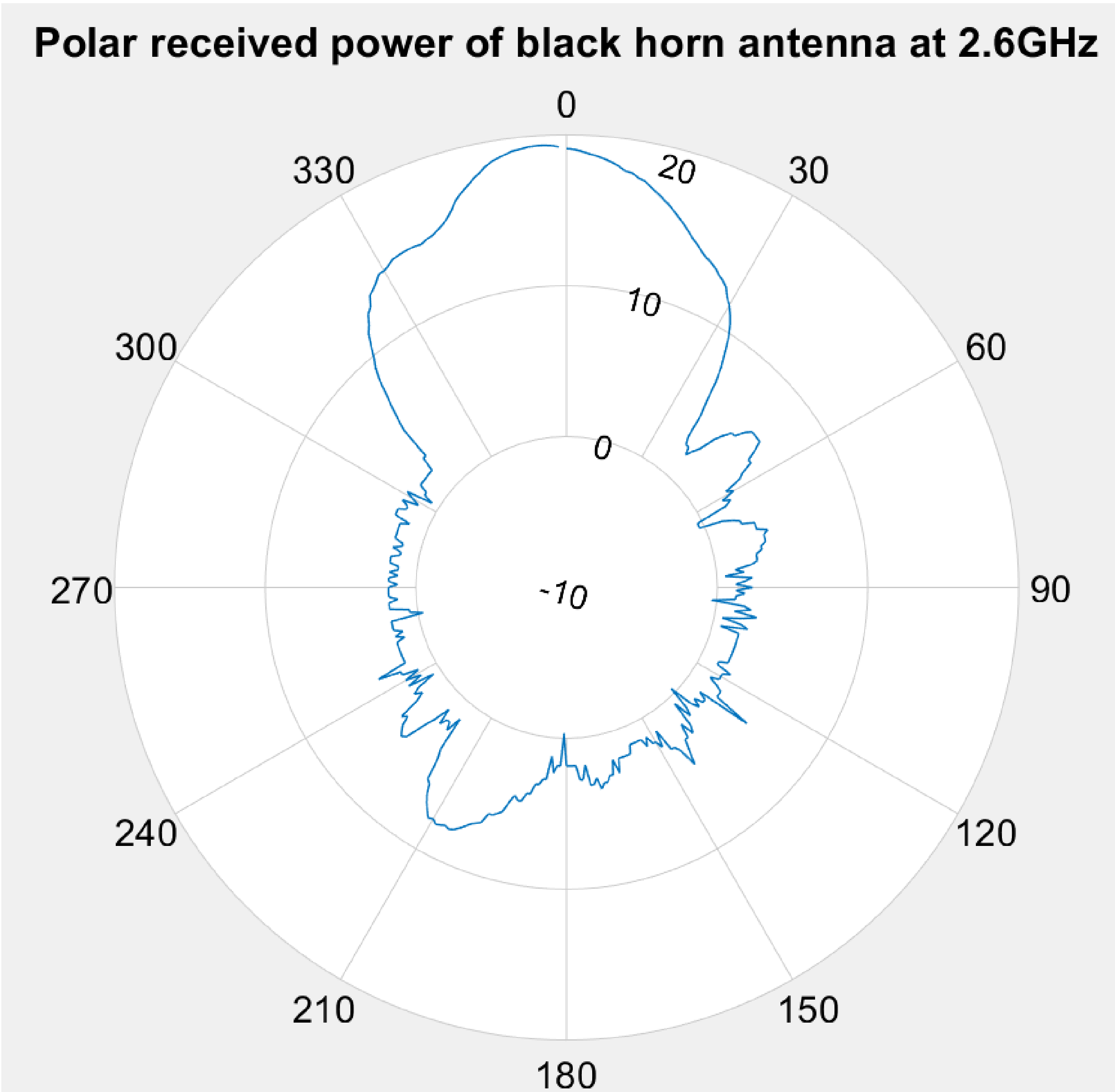
II. Red horn antenna:



Black horn:

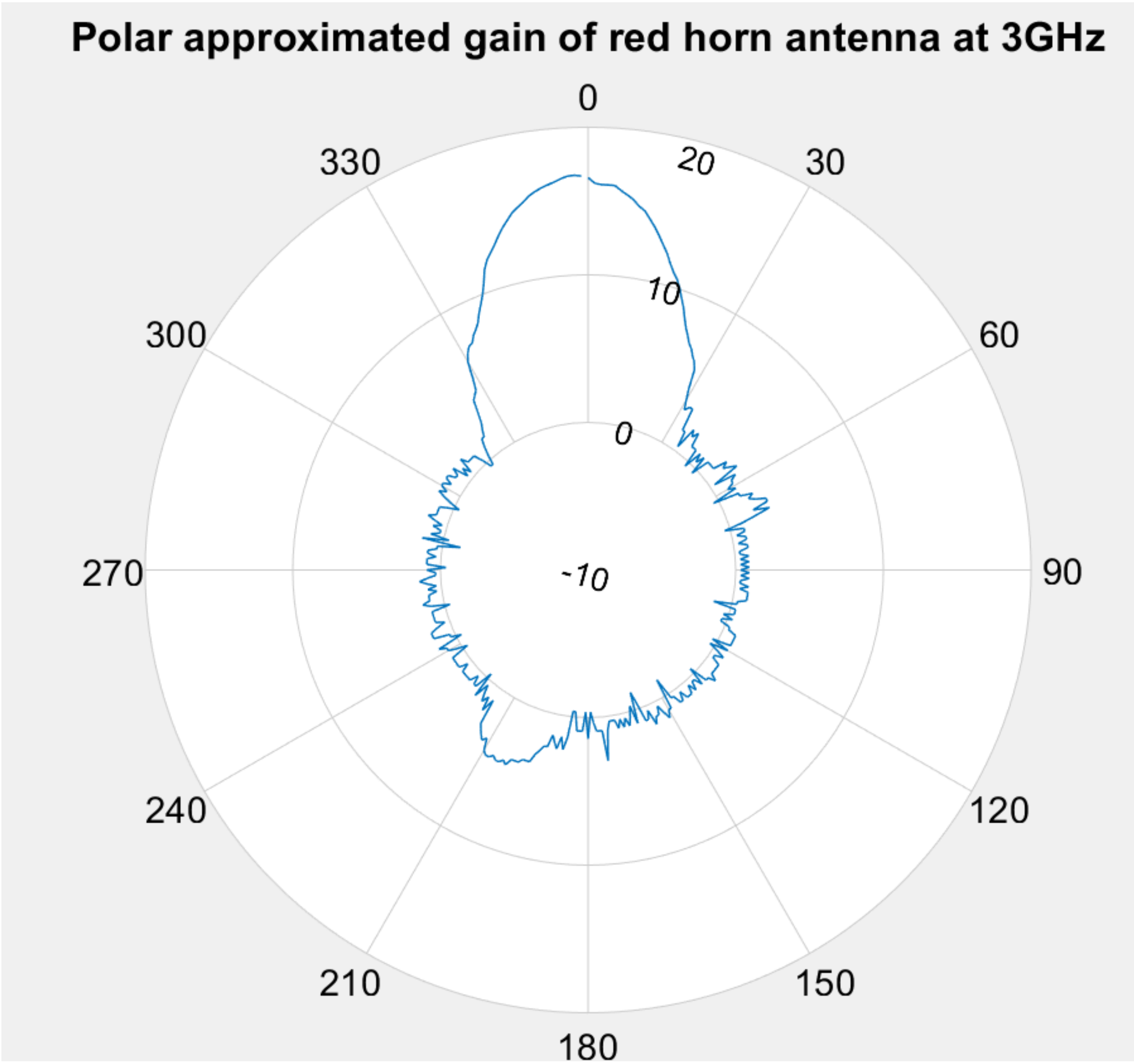


The approximated HPBW is 32 degrees. The approximated gain is 15.8dB and the Side lobes level (SLL) is -10.1 dB relative to the main lobe. The SLL is difference in gain between the maximum sidelobe and the main lobe.

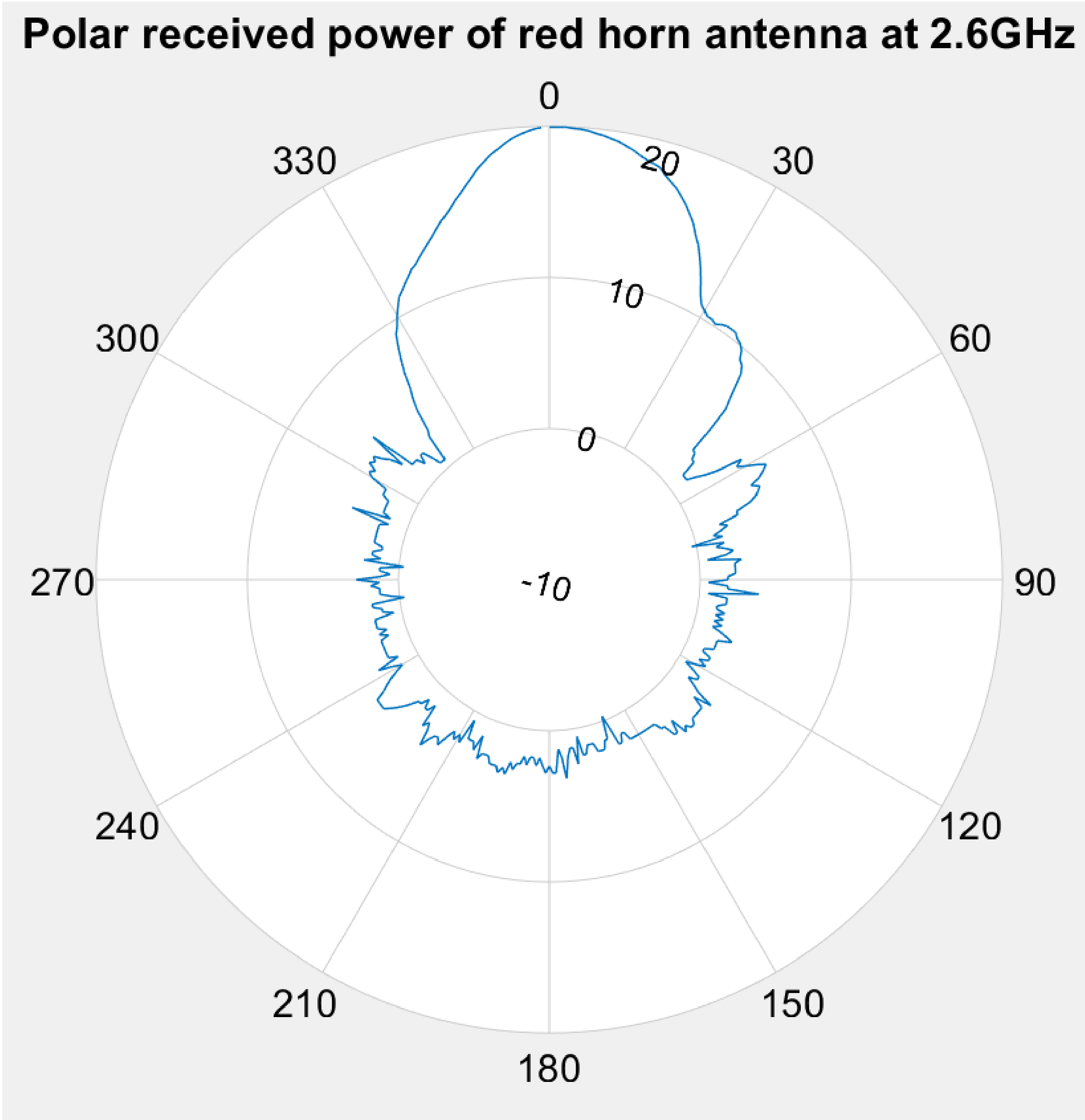


The HPBW is 32 degrees, The maximum Gain is 19.3dB. The SLL is -11.4dB.

Red horn antenna:

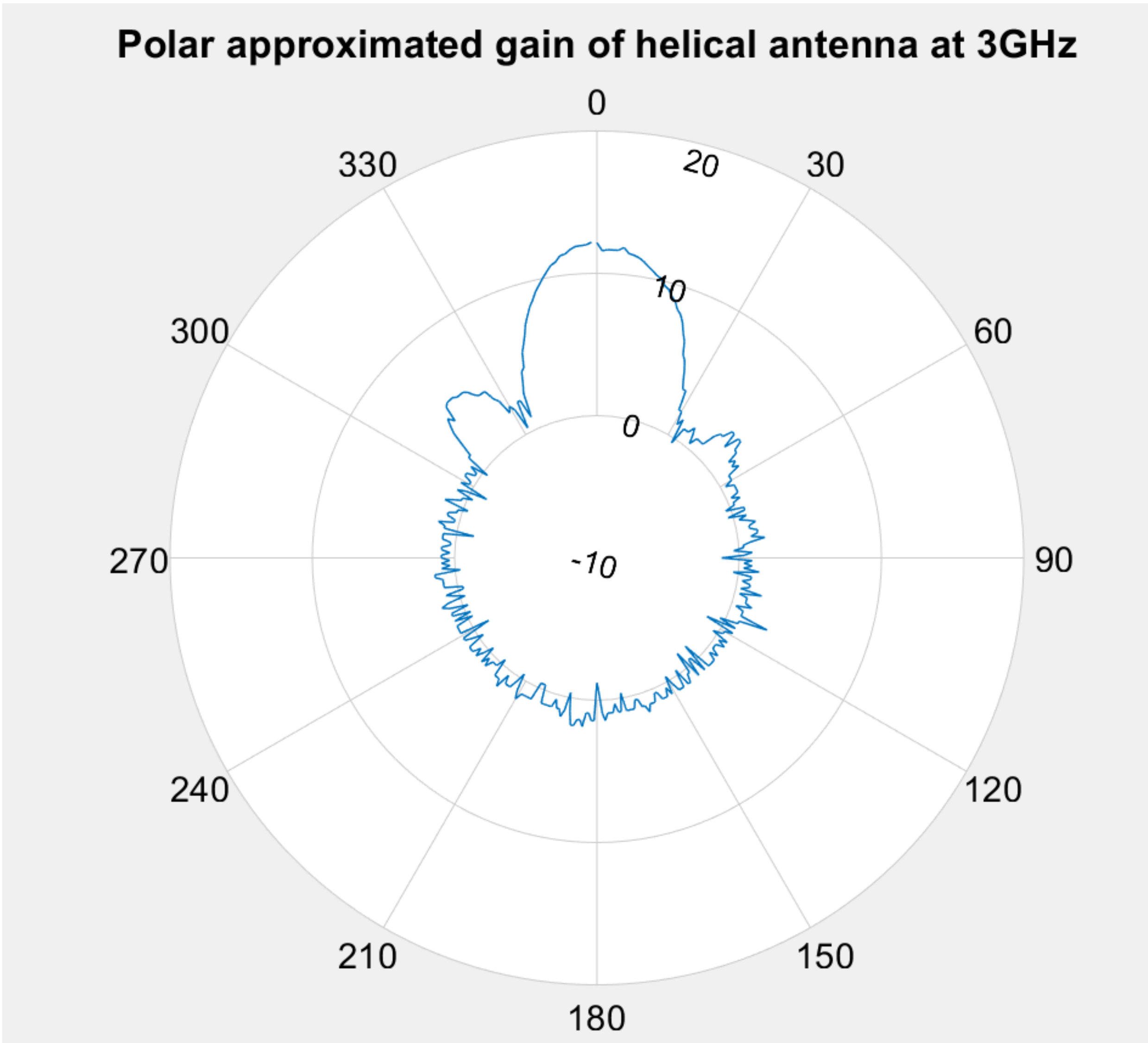


The HPBW is 26 degrees, the max gain is 16.8 dB, and the SLL is -12.4dB.

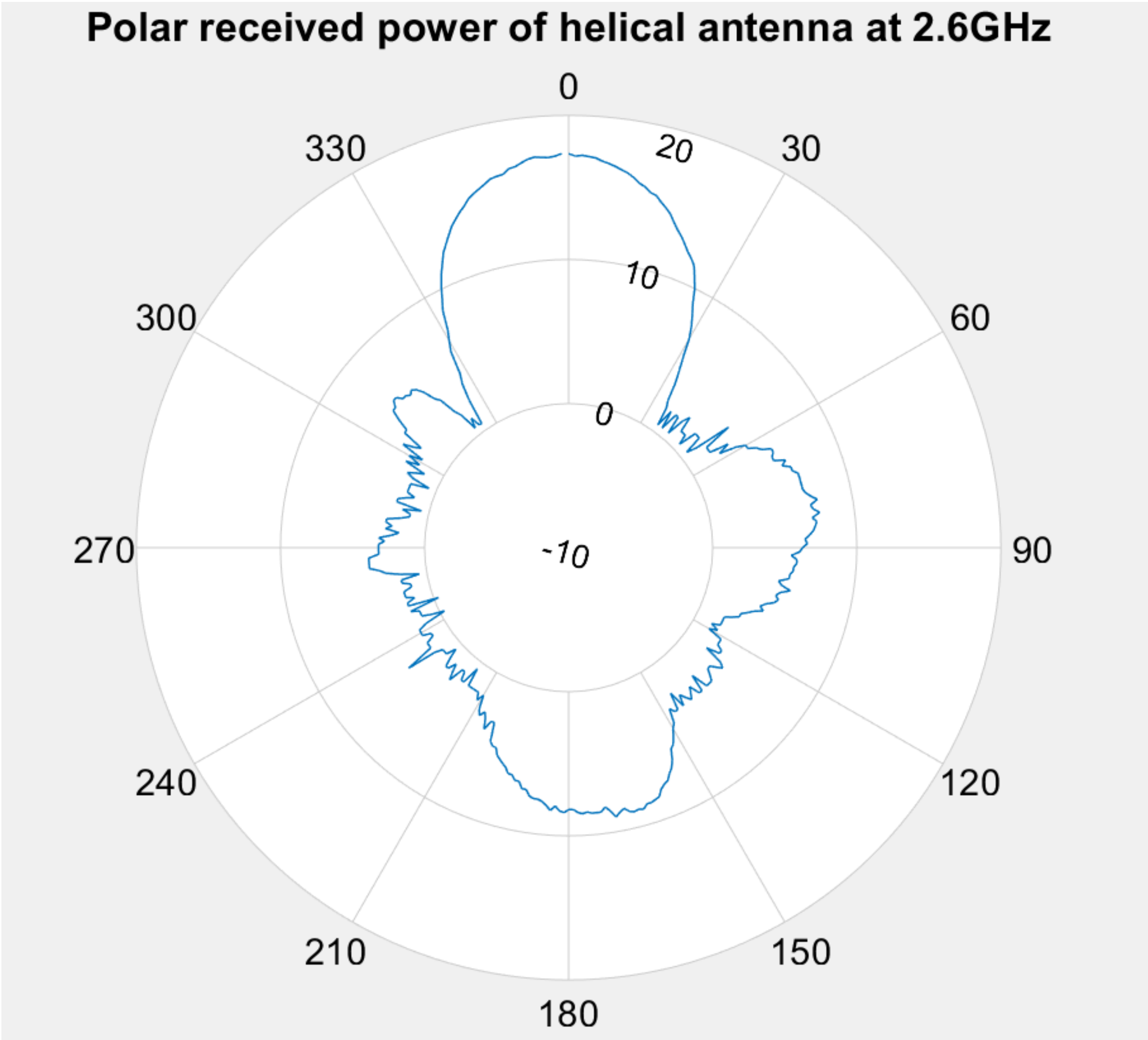


The HPBW is 31 degrees, the max Gain is 20 dB, and the SLL is -13.7dB.

Helical antenna:



The HPBW is 30 degrees, the maximum gain is 12.6dB, and the SLL is -12.6dB.



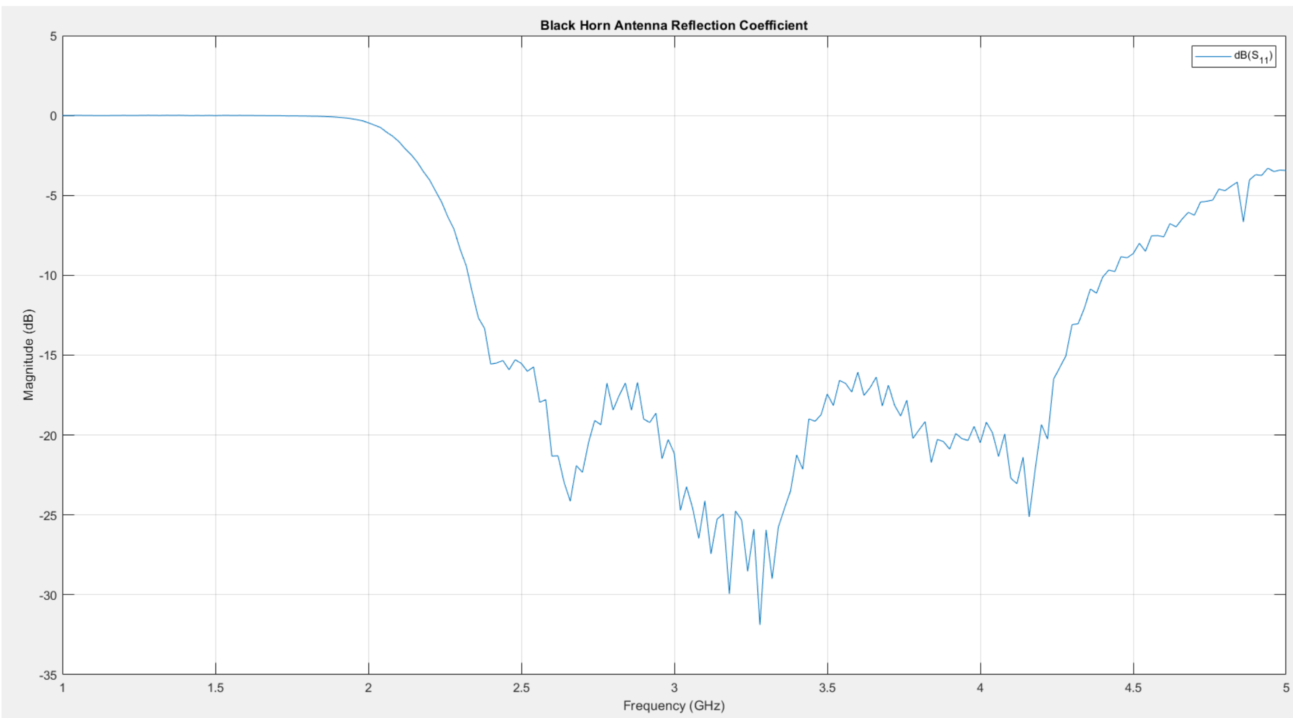
The HPBW is 36 degrees, the maximum gain is 17.4dB, the SLL is -8.38dB.

S-Parameter results:

The reflection coefficient of each of the antennas was measured using a vector network analyzer over a range of frequencies from 1.5 GHz. The -10dB bandwidth of each antenna was calculated.

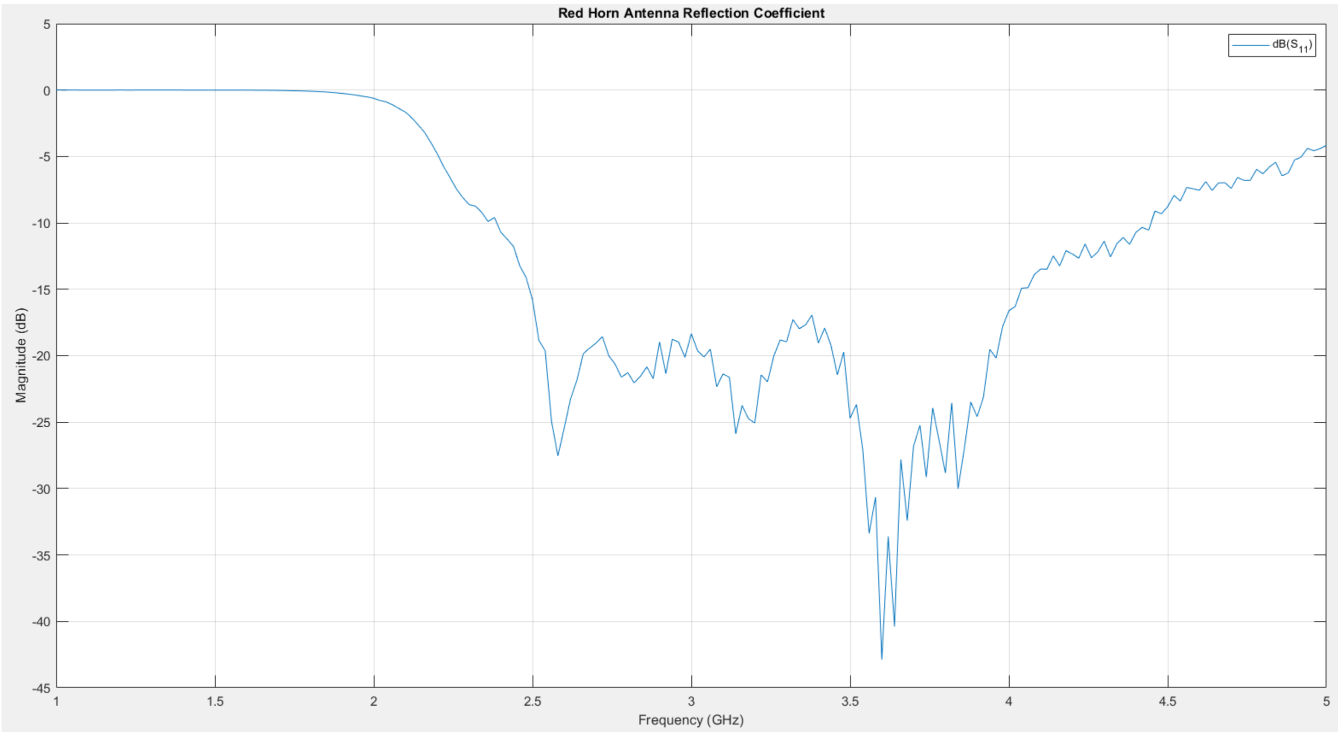
Black Horn Antenna:

- Flow=2.326GHz
- Fhigh=4.4GHz
- -10 dB BW=2.074 GHz



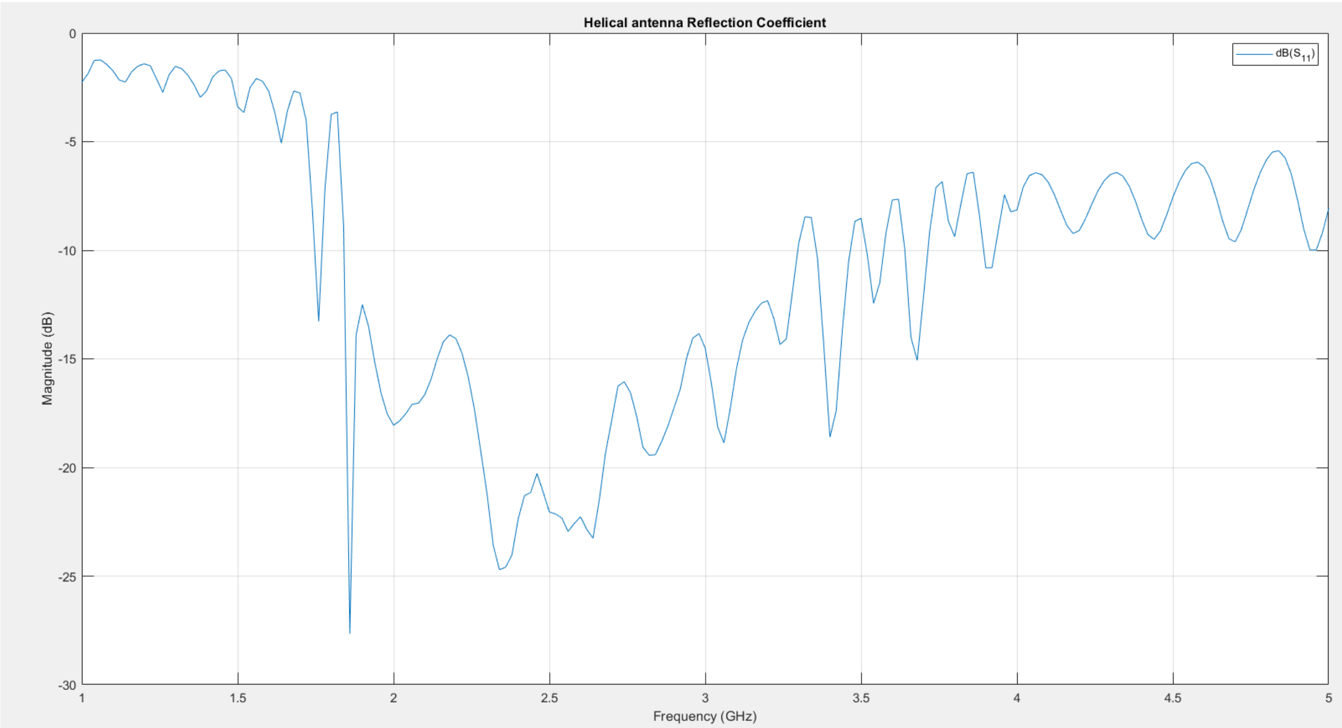
Red horn antenna:

- Flow=2.36GHz
- Fhigh=4.45GHz
- -10dB BW= 2.09 GHz



Helical antenna:

- Flow=1.841GHz
- Fhigh= 3.3GHz
- -10 dB BW=1.459 GHz



Discussion and conclusions

First, the black horn antenna, showed simulated results at 3GHz with a maximum gain of around 15.65dB while the practical results showed a maximum gain of 15.8dB. Second, the red horn antenna, showed simulated results at 3GHz with a maximum gain of around 15.96dB while the practical results showed a maximum gain of 16.8dB. Third, the helical antenna, showed simulated results at 3GHz with a maximum gain of around 13.6 while the practical results showed a maximum gain of 12.6dB. Overall, we are happy with our results since we managed to successfully build and design our antenna while meeting the desired design specifications. We could have improved the performance of our horn antennas through making the interior surface much smoother to avoid reflections. As for the helical antenna, we could have added an input impedance matching circuit to achieve a typical input impedance of 150 ohms. Additionally, helical antennas have higher input impedance than the characteristic impedance of the coaxial cable. Therefore, helical antennas have higher reflection coefficients and hence lower gain values.