CURIE: Cubesat Radio Interferometry Experiment
UHF and S-Band Antenna Design

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July 26, 2018

I. UHF and S-Band Patch Antennas added to CubeSat structure: No Wire Antennas

Simulation stage performed with UHF and S-Band single patch antennas added to each side of the CubeSat structure, according to the required dimensions and locations on the Cube, as shown on previous report. UHF substrate dimensions are 8.5 cm (length) by 9 cm (width), and S-Band substrate dimensions are 5 cm (length) by 4.5 cm (length). Simulations performed with CST Studio Suite 2017 ©.

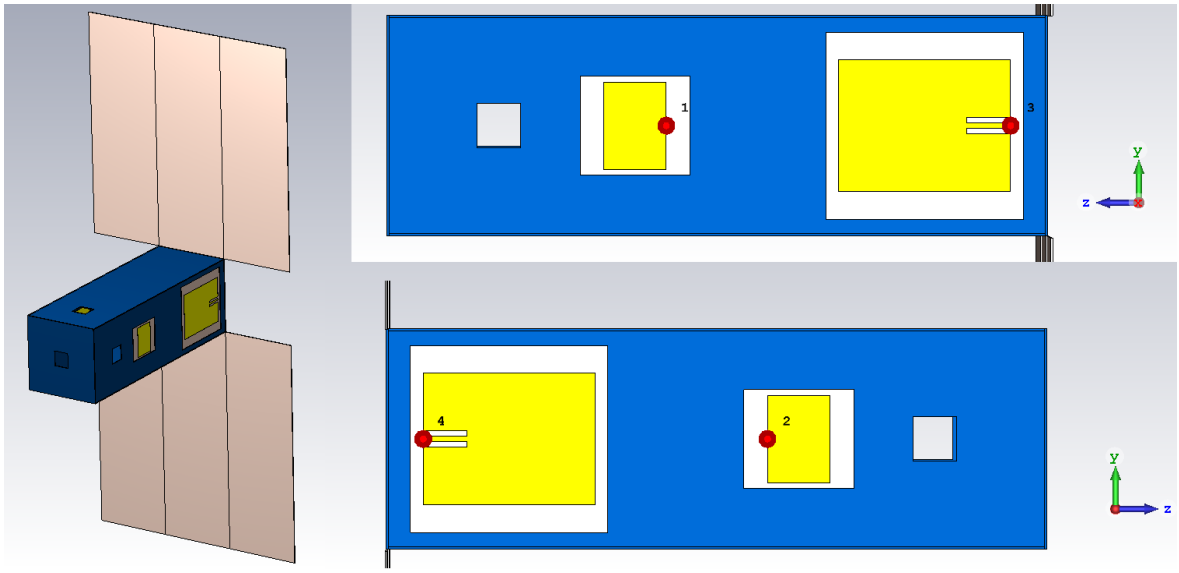

Figure 1.1: UHF Patch Antenna and S-Band Patch Antenna added to each side of CubeSat structure. Perspective, Left- and Right-side views.

Parameter List

Name	Expression	Value	Description	Type
freq_S	2.4	2.4	Frequency - S-Band [GHz]	Frequency
freq_UHF	0.915	0.915	Frequency - UHF [GHz]	Frequency
Gpatch_S	7 + Gpatch_U + Wsubs_U - 0.8	16.3	Distance From UHF Edge to S-Band Patch [cm]	Length
Hbox	10	10	Box Height (Y Axis) [cm]	Length
Hpan	10	10	Panel Height/Width (X Axis) [cm]	Length
Lambda	68.49315	68.493...	Wavelength [cm]	Length
Lbox	30	30	Box Length (Z Axis) [cm]	Length
Lpan	30	30	Panel Length (Y Axis) [cm]	Length
Lpatch_S	2.8579	2.8579	S-Band Patch Length (Z Axis) [cm] (Orig = 2.85...	Length
Lsubs_S	4.5 + 0.5	5	S-Band Substrate Length (Z Axis) [cm]	Length
Lwire	240	240	Wire Antenna Length [cm]	Length
MPHole	2	2	Wire Antenna Box Hole	Length
Rwire	0.016	0.016	Wire Antenna Radius [cm]	Length
Tbox	0.1	0.1	Box Thickness [cm]	Length

Parameter List

Name	Expression	Value	Description	Type
Tpan	0.08	0.08	Panel Thickness [cm]	Length
Tpatch	0.005	0.005	Patch Thickness (X Axis) [cm]	Length
Tsubs	0.16	0.16	Substrate Thickness (X Axis) [cm]	Length
Wpatch_S	3.9593	3.9593	S-Band Patch Width (Y Axis) [cm] (Orig = 3.5593)	Length
Wposc	Hbox/2	5	Wire Antena Central Position [cm]	Length
Wsubs_S	4.5	4.5	S-Band Substrate Width (Y Axis) [cm]	Length
Gpatch_U	Tbox + 1	1.1	Distance From Box Edge to UHF Patch [cm]	Length
Lpatch_U	6	6	UHF Patch Length (Z Axis) [cm]	Length
Lsubs_U	Lpatch_U+2.5	8.5	UHF Substrate Length (Z Axis) [cm]	Length
Wpatch_U	7.825	7.825	UHF Patch Width (Y Axis) [cm]	Length
Wstrip_U	0.25	0.25	UHF Feed Strip Width (X Axis) [cm]	Length
Wsubs_U	Wpatch_U+1.575 - 0.4	9	UHF Substrate Width (Y Axis) [cm]	Length
x0_U	Wstrip_U	0.25	UHF Patch - Inset Gap - Width (X Axis) [cm]	Length
y0_U	2	2	UHF Patch - Inset Gap - Length (Y Axis) [cm]	Length

Figure 1.2: Parameter list for CubeSat Structure design.

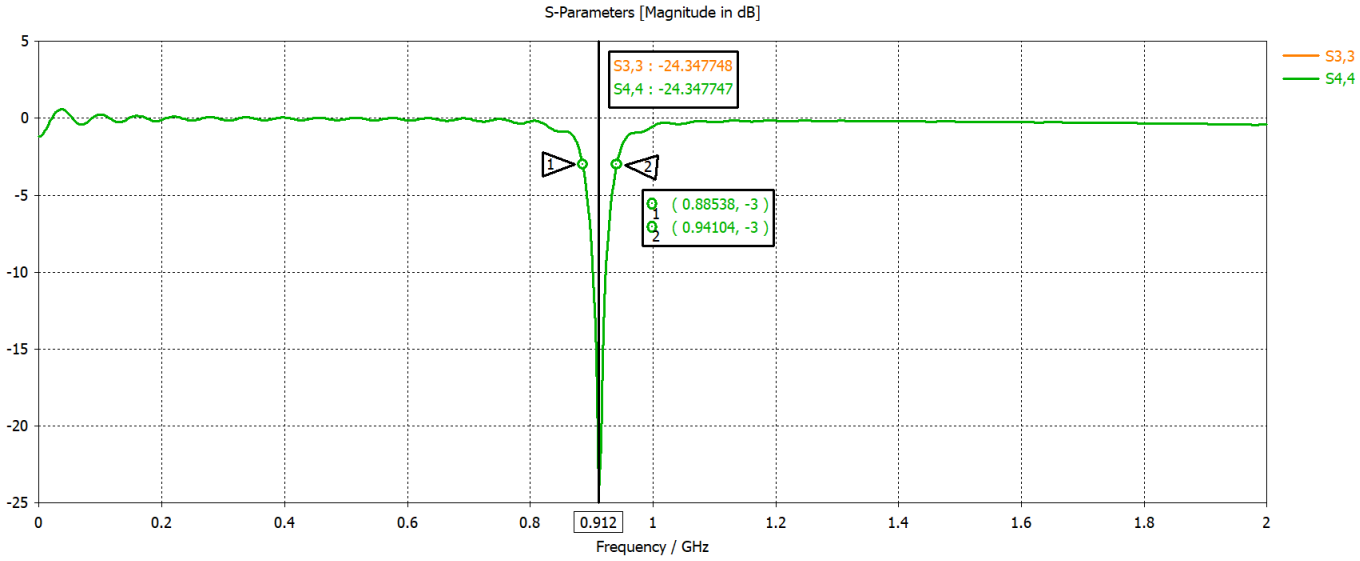

Figure 1.3: Input Reflection Coefficient (S11 Parameter) for UHF Patch Antenna added CubeSat structure.

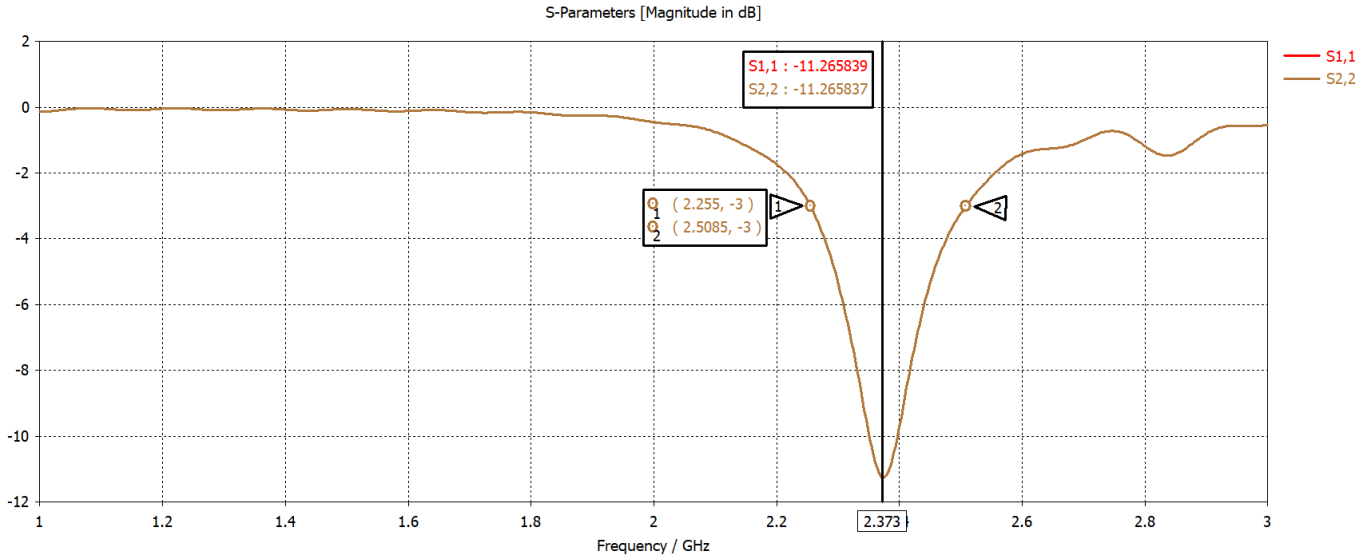

Figure 1.4: Input Reflection Coefficient (S11 Parameter) for S-Band Patch Antenna added CubeSat structure.

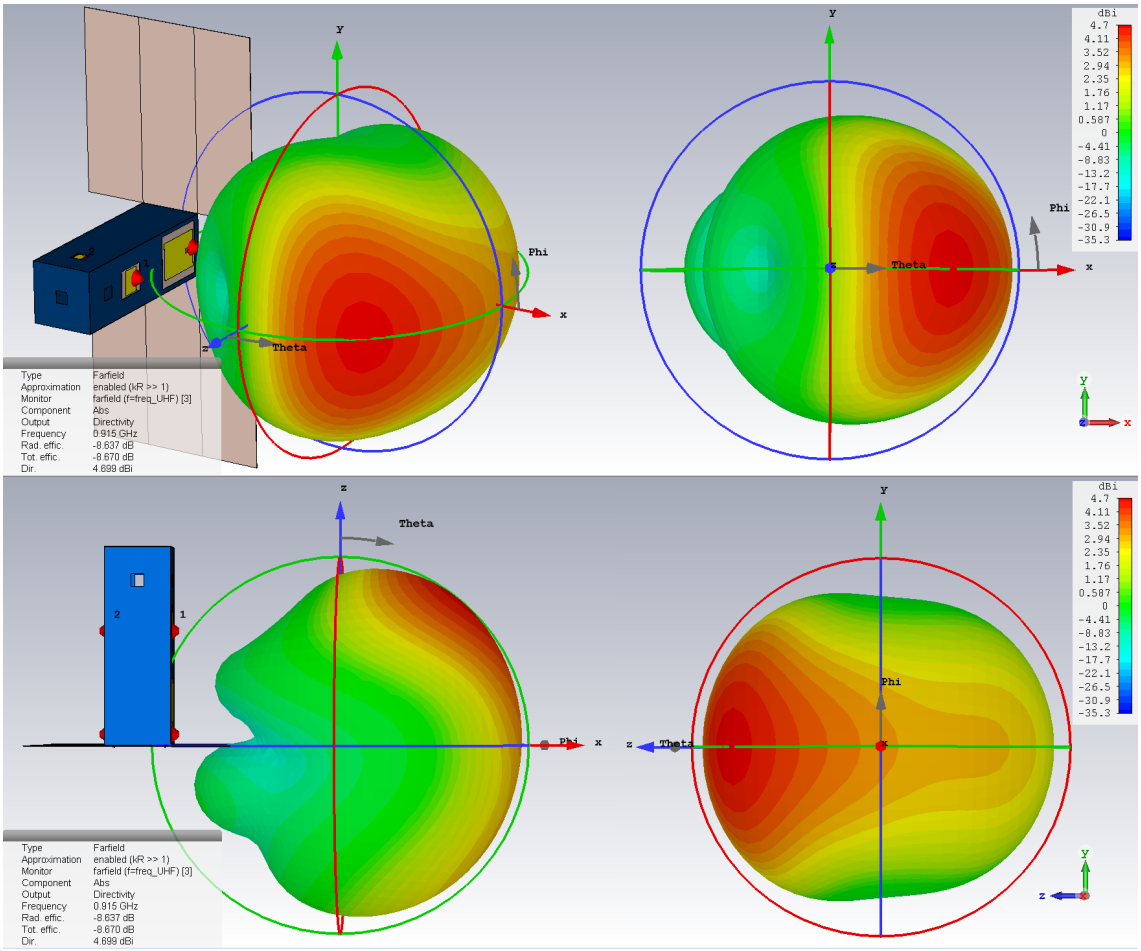

Figure 1.5: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure. **Directivity**

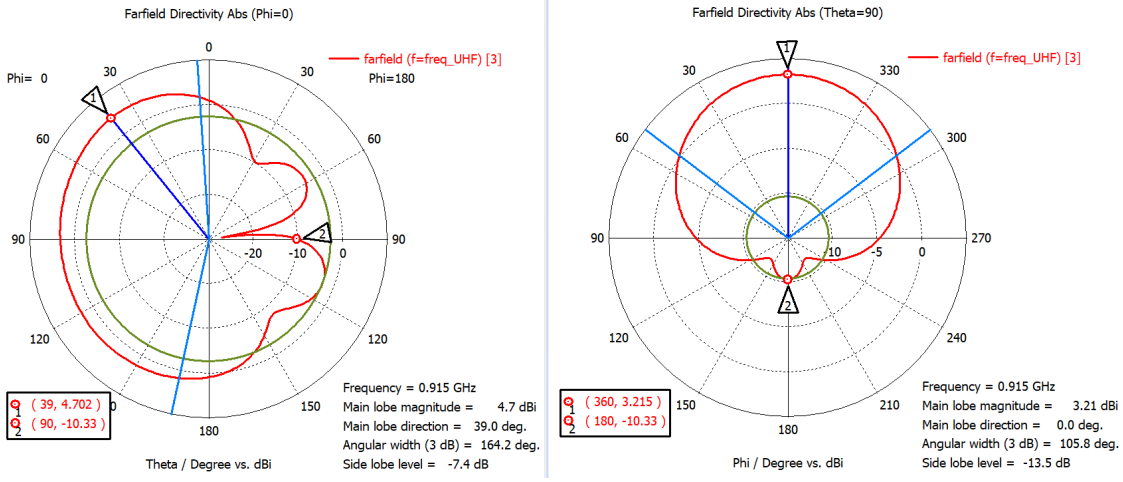

Figure 1.6: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure. **Directivity (Polar View)**

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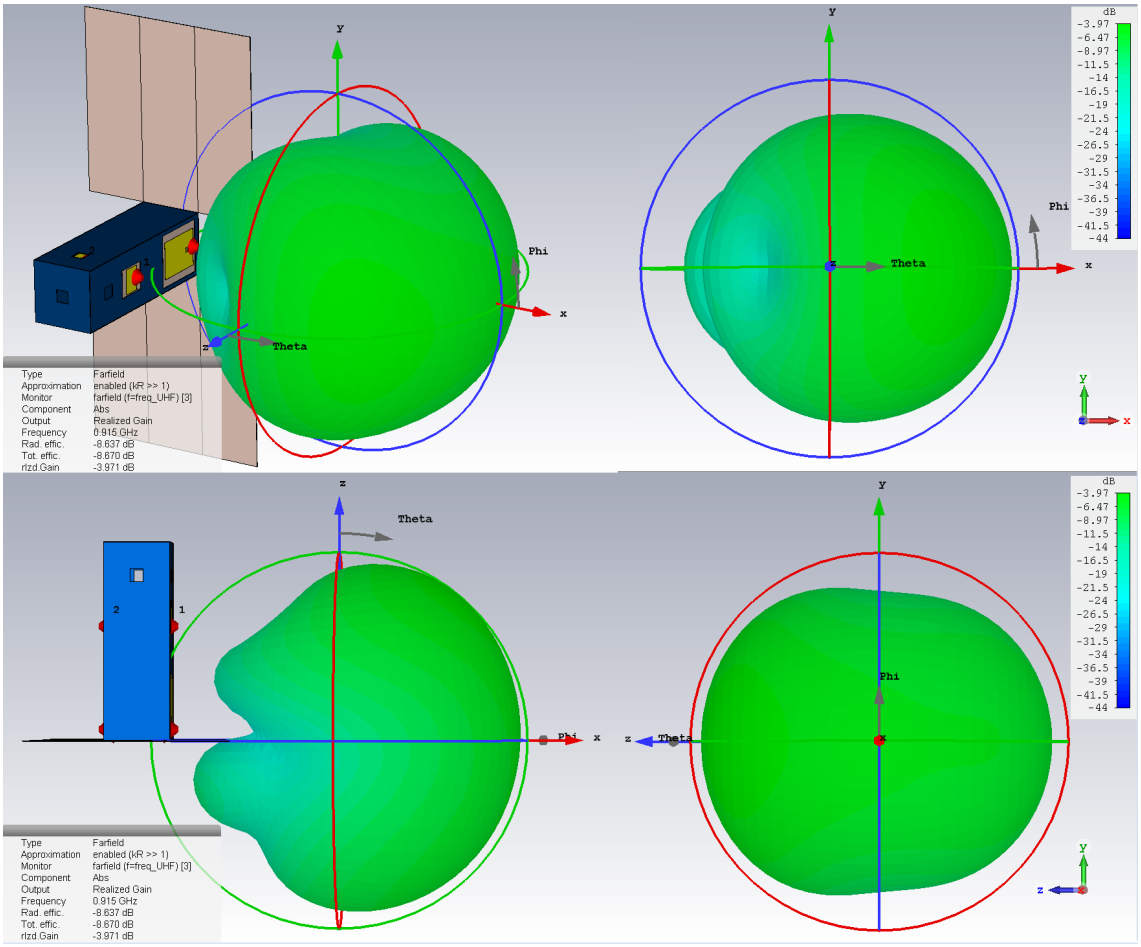

Figure 1.7: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure. **Realized Gain**

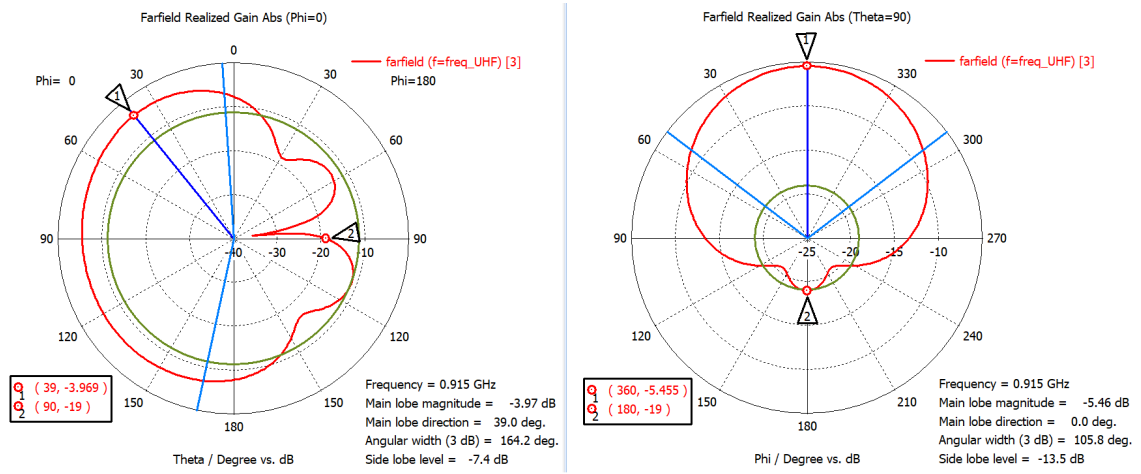

Figure 1.8: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure. **Realized Gain (Polar View)**

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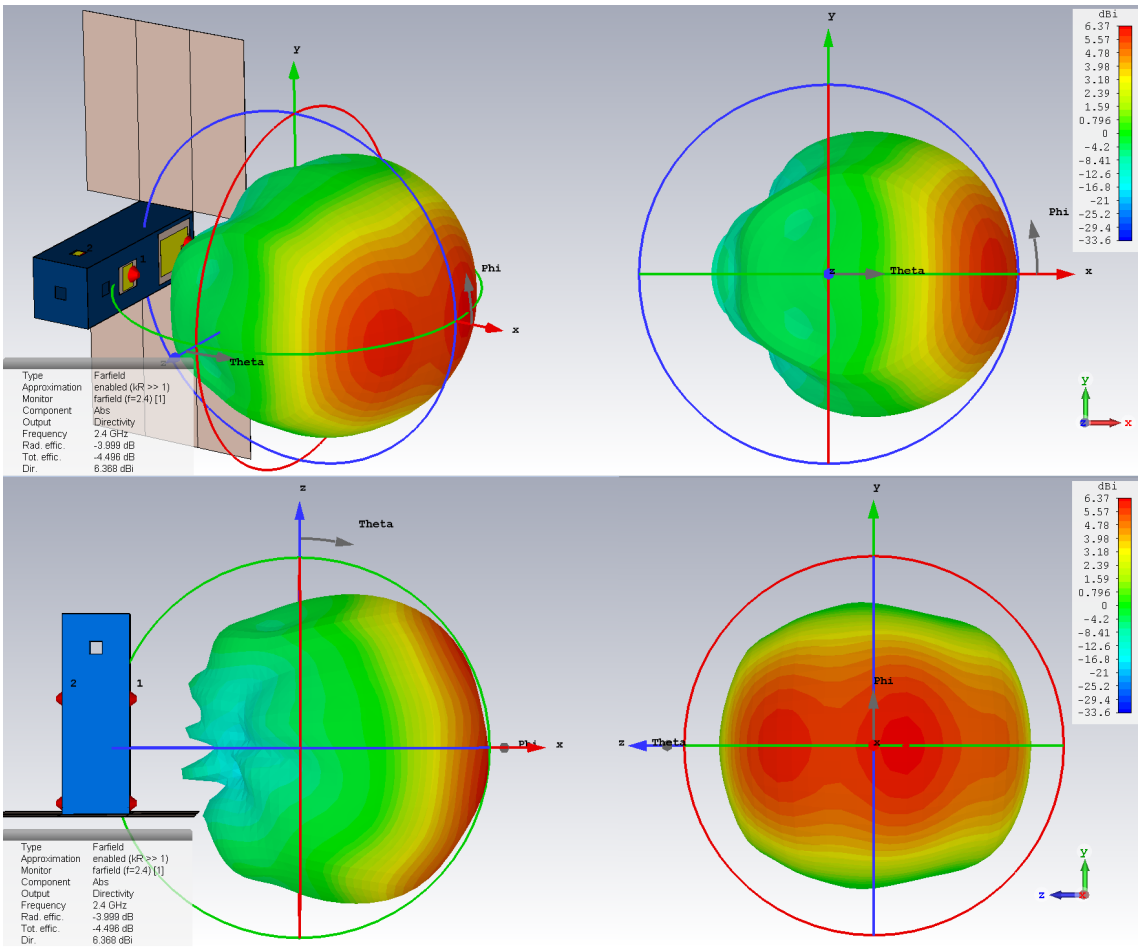

Figure 1.9: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure. **Directivity**

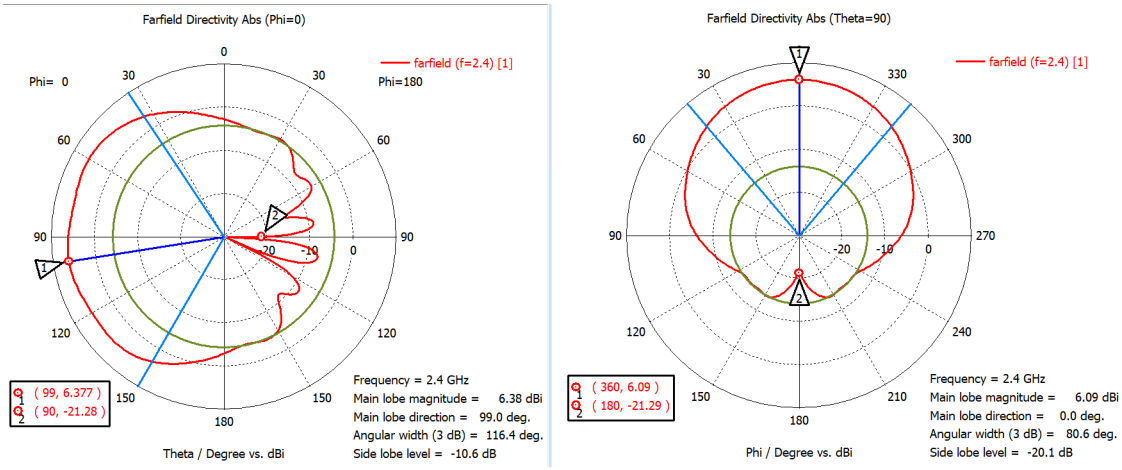

Figure 1.10: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure. **Directivity (Polar View)**

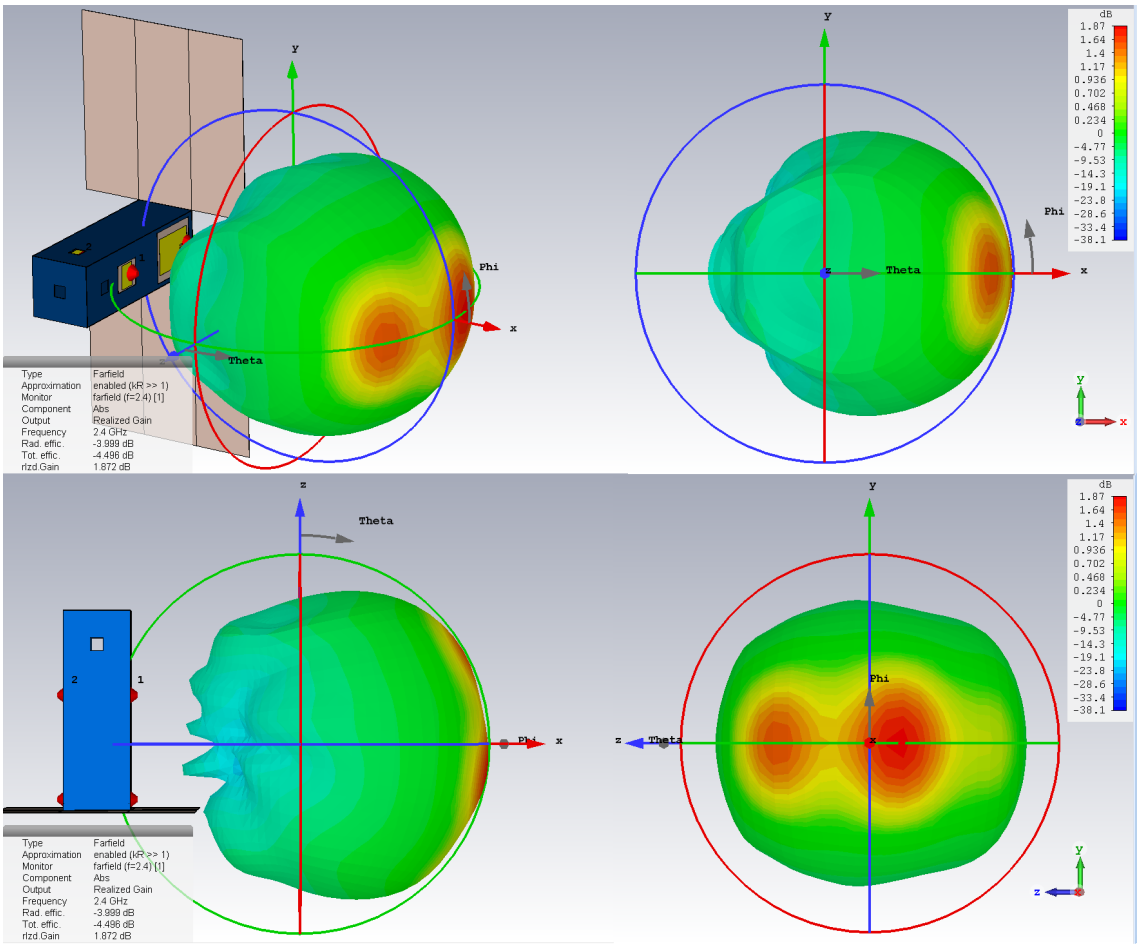

Figure 1.11: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure. **Realized Gain**

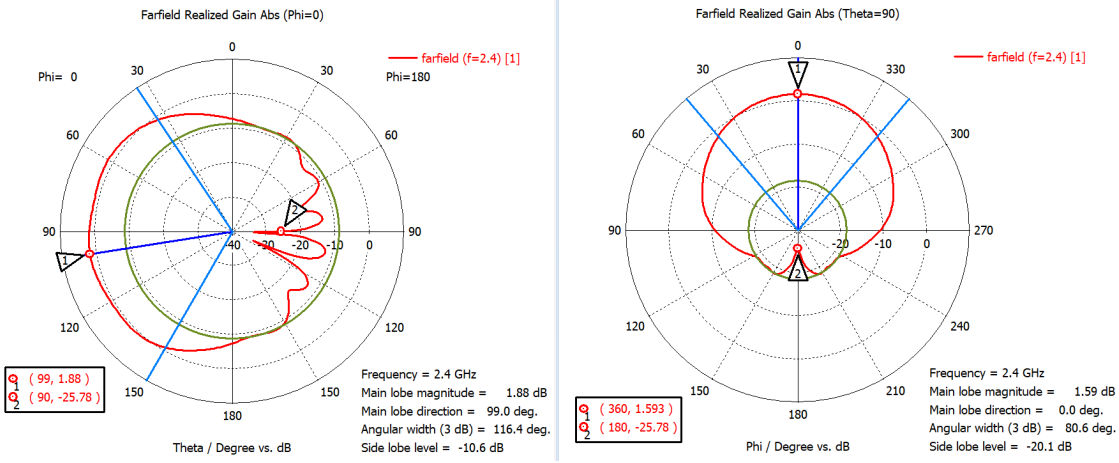

Figure 1.12: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure. **Realized Gain (Polar View)**

II. UHF and S-Band Patch Antennas added to CubeSat structure: 2.5m Wire Antennas Off

Simulation stage performed with UHF and S-Band single patch antennas added to each side of the CubeSat structure, and 2.5m Wire antennas located on each side towards the front of the CubeSat structure. Simulations performed with CST Studio Suite 2017 ©.

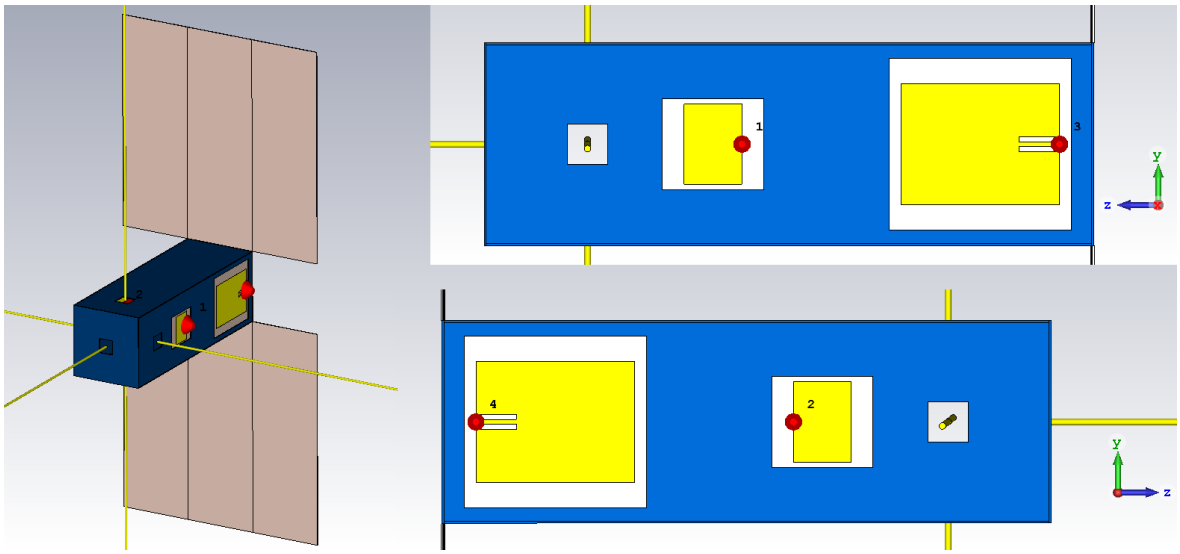

Figure 2.1: UHF Patch Antenna and S-Band Patch Antenna added to each side of CubeSat structure, with 2.5m Wire Antennas. Perspective, Left- and Right-side views.

Parameter List

Name	Expression	Value	Description	Type
freq_S	2.4	2.4	Frequency - S-Band [GHz]	Frequency
freq_UHF	0.915	0.915	Frequency - UHF [GHz]	Frequency
Gpatch_S	7 + Gpatch_U + Wsubs_U - 0.8	16.3	Distance From UHF Edge to S-Band Patch [cm]	Length
Hbox	10	10	Box Height (Y Axis) [cm]	Length
Hpan	10	10	Panel Height/Width (X Axis) [cm]	Length
Lambda	68.49315	68.49315	Wavelength [cm]	Length
Lbox	30	30	Box Length (Z Axis) [cm]	Length
Lpan	30	30	Panel Length (Y Axis) [cm]	Length
Lpatch_S	2.8579	2.8579	S-Band Patch Length (Z Axis) [cm] (Orig = 2.8579)	Length
Lsubs_S	4.5 + 0.5	5	S-Band Substrate Length (Z Axis) [cm]	Length
Lwire	240	240	Wire Antenna Length [cm]	Length
MPHole	2	2	Wire Antenna Box Hole	Length
Rwire	0.16	0.16	Wire Antenna Radius [cm]	Length
Tbox	0.1	0.1	Box Thickness [cm]	Length

Parameter List

Name	Expression	Value	Description	Type
Tpan	0.08	0.08	Panel Thickness [cm]	Length
Tpatch	0.005	0.005	Patch Thickness (X Axis) [cm]	Length
Tsubs	0.16	0.16	Substrate Thickness (X Axis) [cm]	Length
Wpatch_S	3.9593	3.9593	S-Band Patch Width (Y Axis) [cm] (Orig = 3.5593)	Length
Wposc	Hbox/2	5	Wire Antena Central Position [cm]	Length
Wsubs_S	4.5	4.5	S-Band Substrate Width (Y Axis) [cm]	Length
Gpatch_U	Tbox + 1	1.1	Distance From Box Edge to UHF Patch [cm]	Length
Lpatch_U	6	6	UHF Patch Length (Z Axis) [cm]	Length
Lsubs_U	Lpatch_U+2.5	8.5	UHF Substrate Length (Z Axis) [cm]	Length
Wpatch_U	7.825	7.825	UHF Patch Width (Y Axis) [cm]	Length
Wstrip_U	0.25	0.25	UHF Feed Strip Width (X Axis) [cm]	Length
Wsubs_U	Wpatch_U+1.575 - 0.4	9	UHF Substrate Width (Y Axis) [cm]	Length
x0_U	Wstrip_U	0.25	UHF Patch - Inset Gap - Width (X Axis) [cm]	Length
y0_U	2	2	UHF Patch - Inset Gap - Length (Y Axis) [cm]	Length

Figure 2.2: Parameter list for CubeSat Structure design.

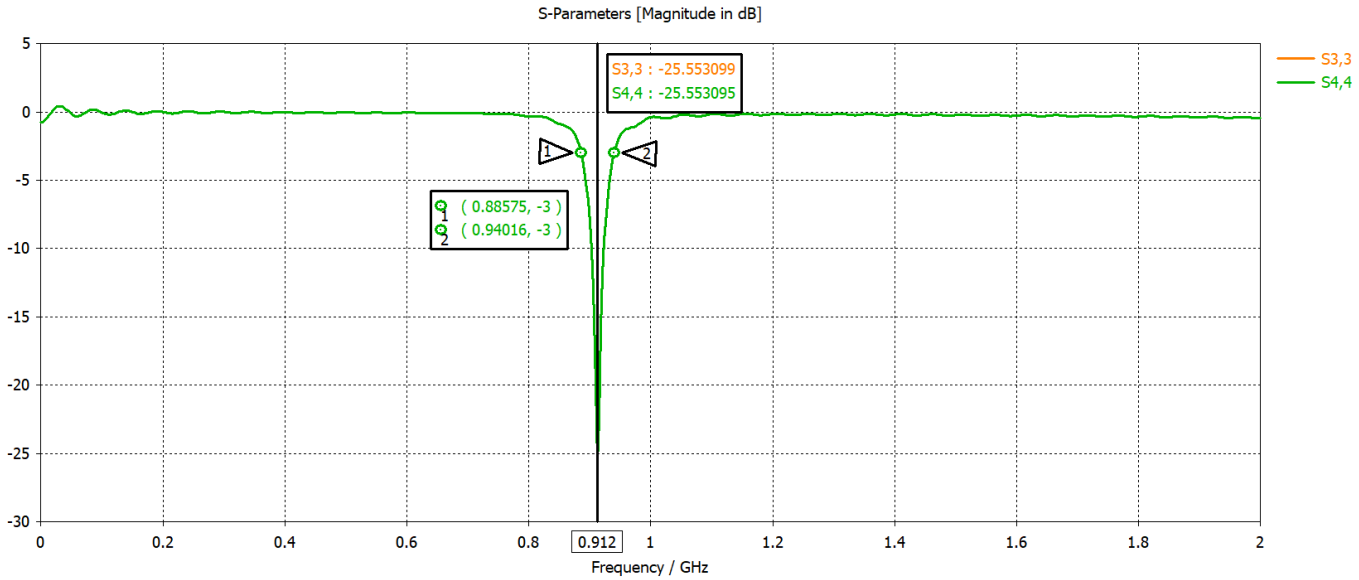

Figure 2.3: Input Reflection Coefficient (S11 Parameter) for UHF Patch Antenna added CubeSat structure, with 2.5m Wire Antennas.

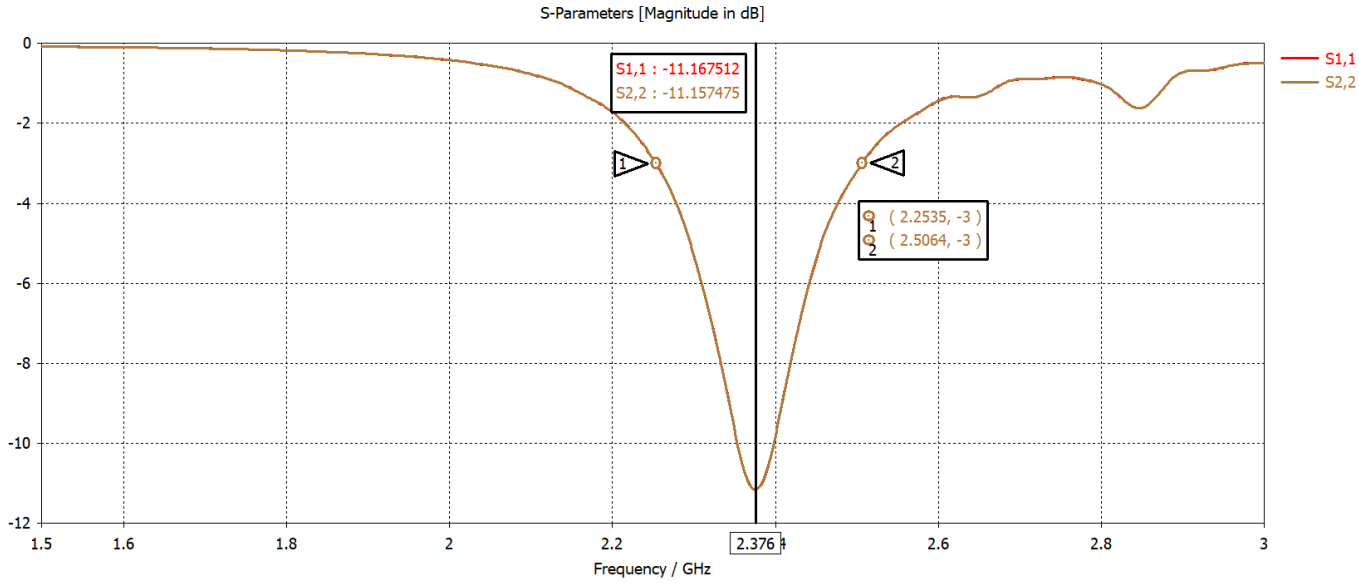

Figure 2.4: Input Reflection Coefficient (S11 Parameter) for S-Band Patch Antenna added CubeSat structure, with 2.5m Wire Antennas.

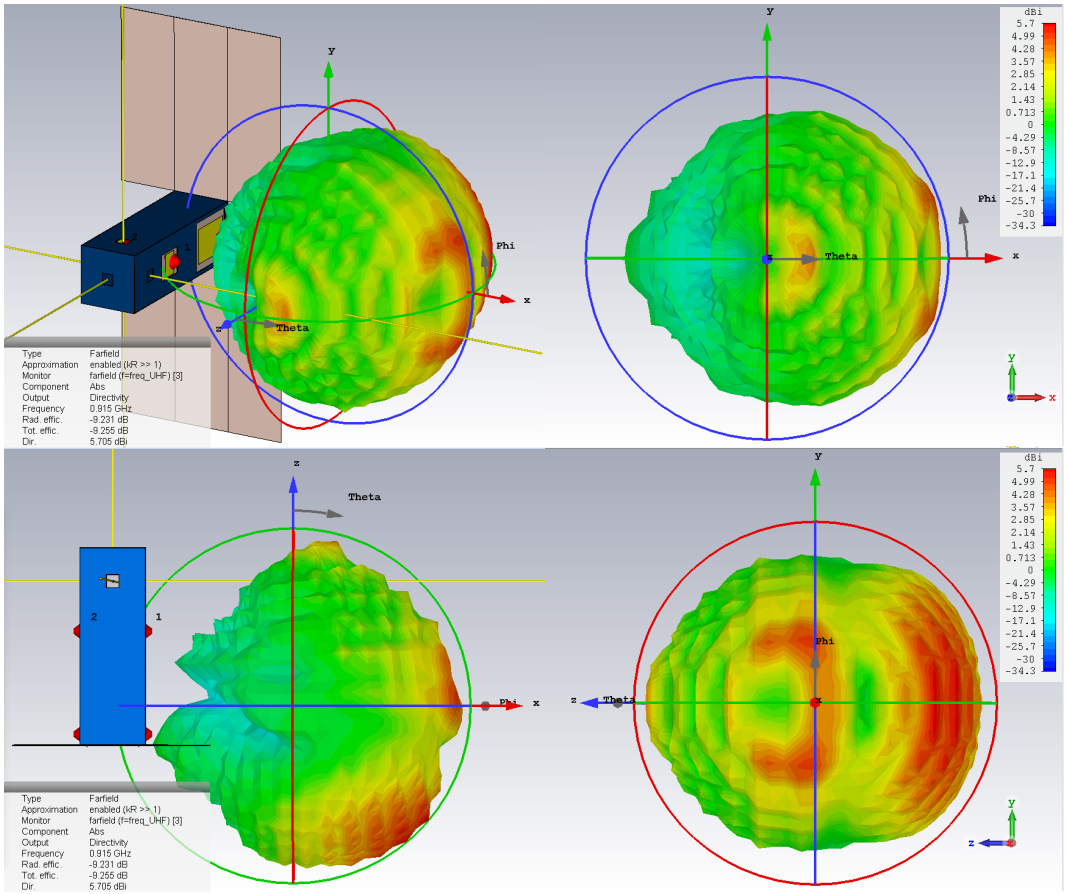

Figure 2.5: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Directivity**

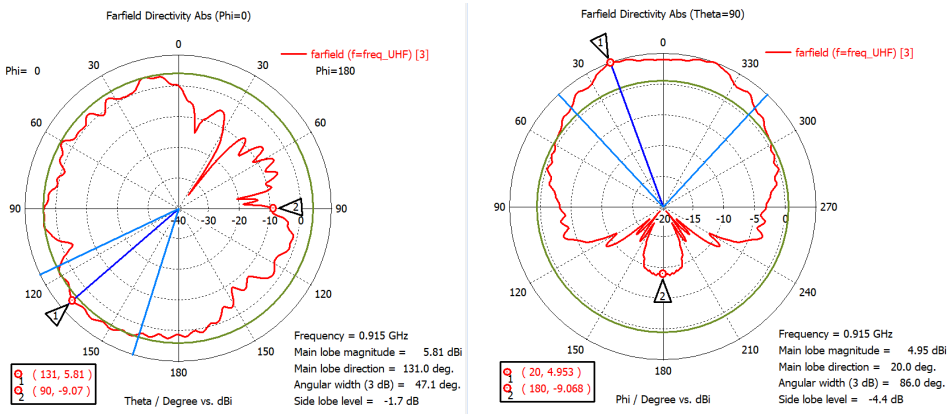

Figure 2.6: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Directivity (Polar View)**

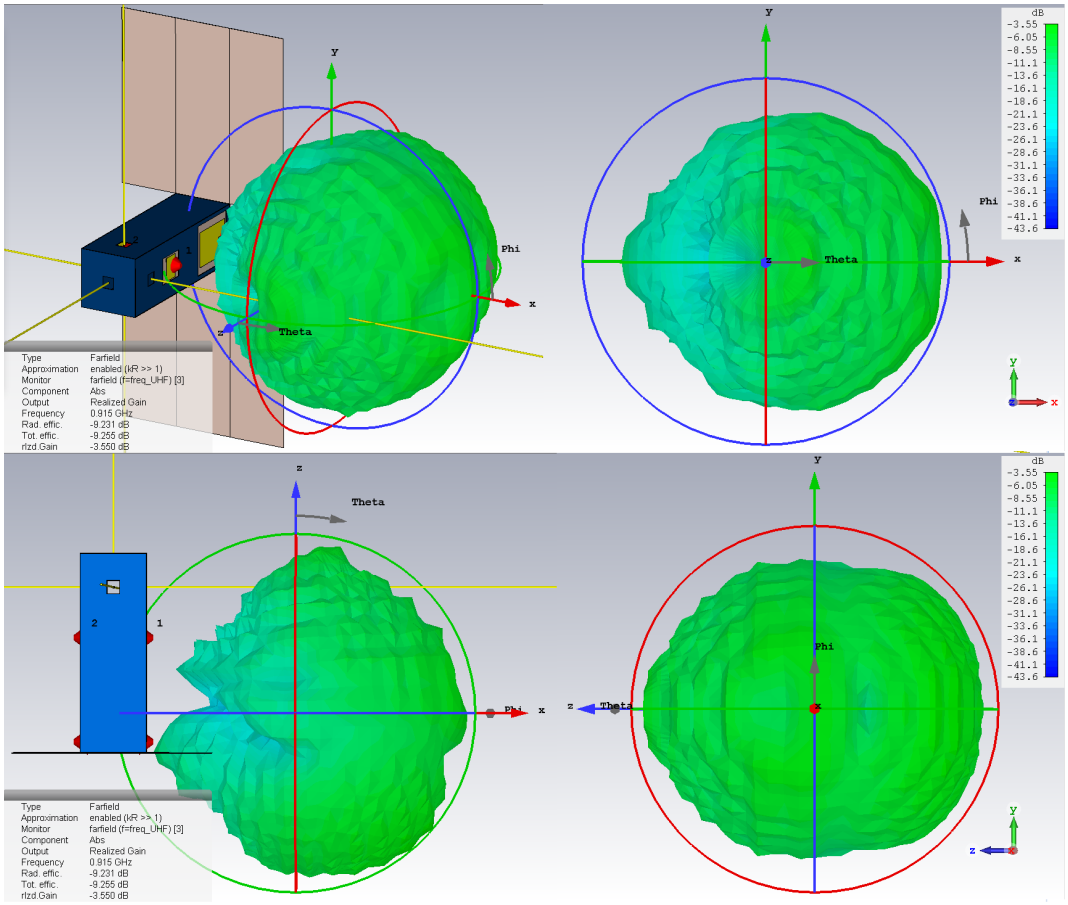

Figure 2.7: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Realized Gain**

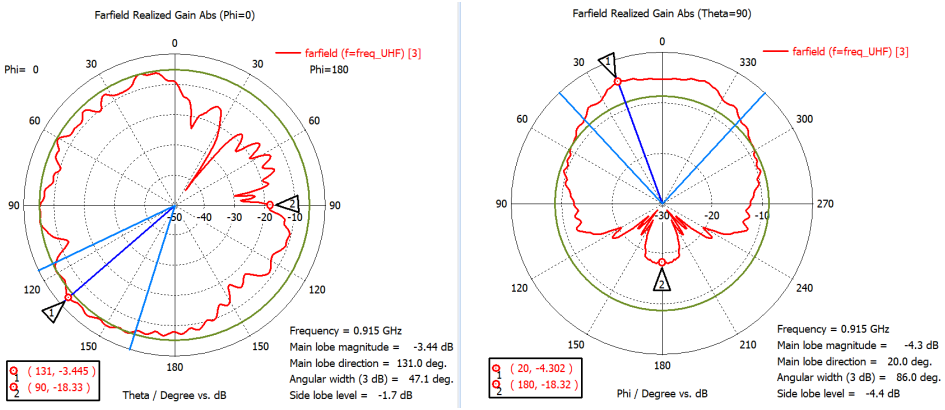

Figure 2.8: Far-field radiation pattern for UHF Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Realized Gain (Polar View)**

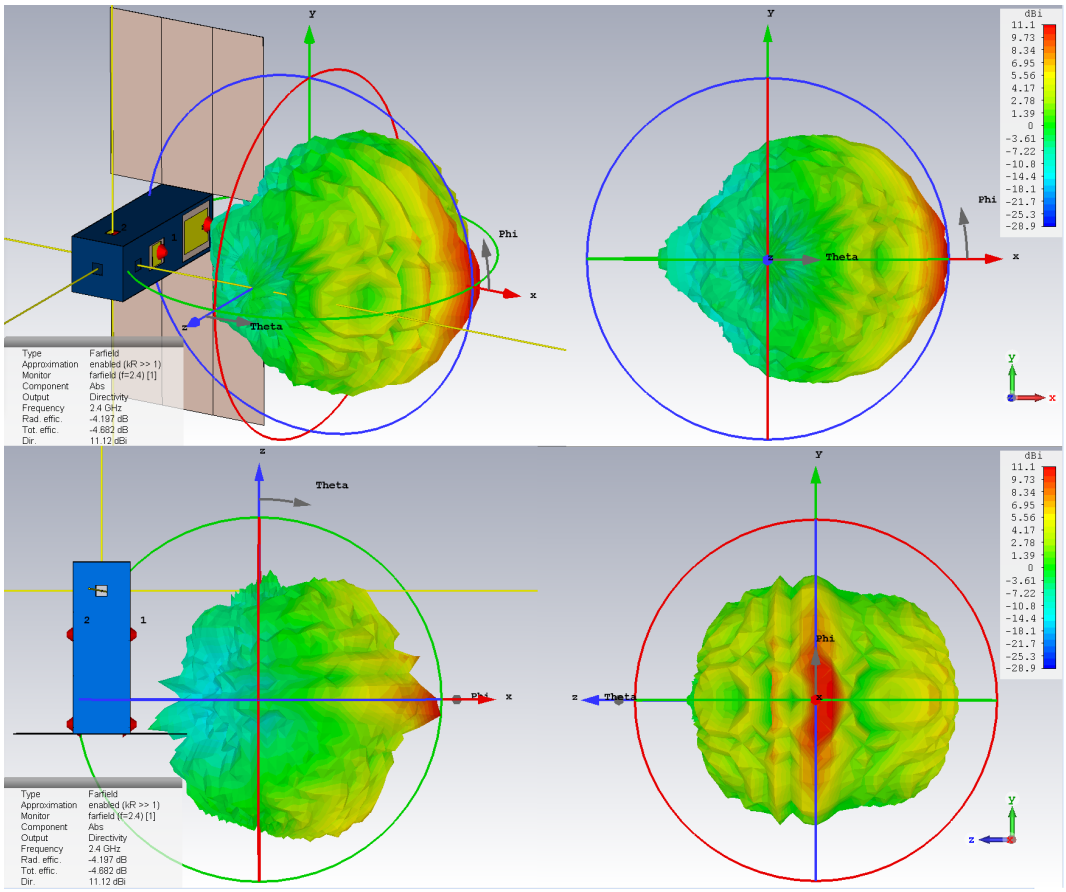

Figure 2.9: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Directivity**

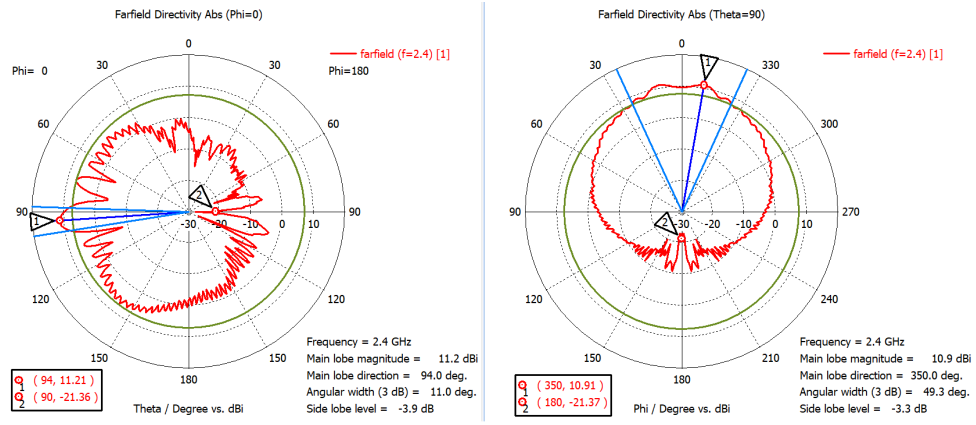

Figure 2.10: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Directivity (Polar View)**

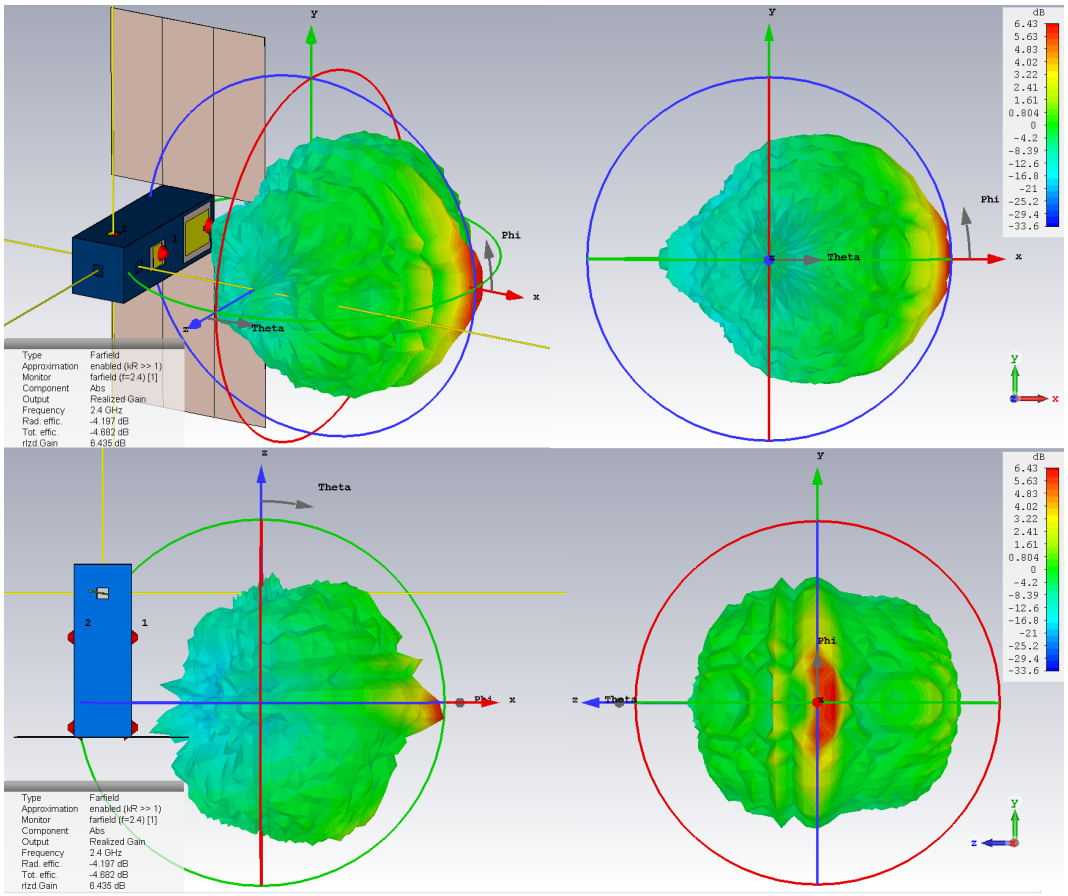

Figure 2.11: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Realized Gain**

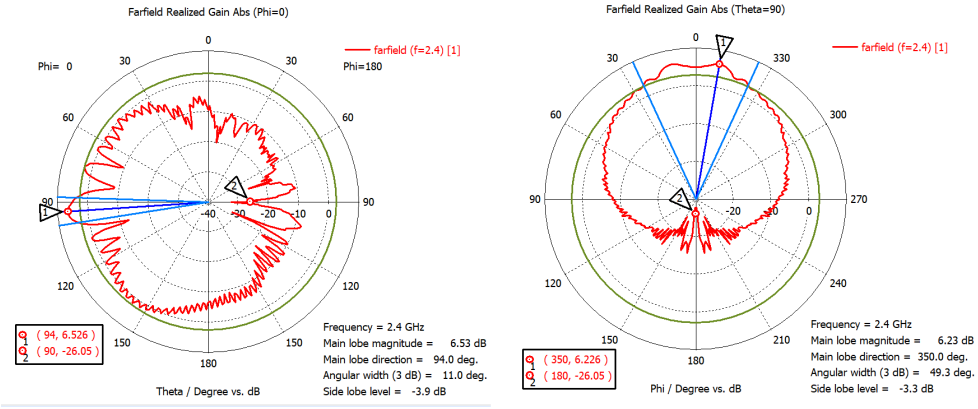

Figure 2.12: Far-field radiation pattern for S-Band Patch Antenna added CubeSat structure, with 2.5m Wire Antennas. **Realized Gain (Polar View)**

Table 1: **For Comparison**, Result Summary for UHF and S-Band Patch Antennas shown on Previous Reports: Isolated Antennas and Antennas added to only One surface of CubeSat structure

PARAMETER	Isolated UHF Rectangular Patch Antenna	Isolated S-Band Rectangular Patch Antenna	Comms Patch antennas added to One Surface of CubeSat structure	
			UHF Antenna	S-Band Antenna
Input Reflection Coefficient (S11 Parameter)	-31.696 dB (at 915 MHz)	-22.271 dB (at 2.406 GHz)	-22.245 dB (at 912 MHz)	-11.079 dB (at 2.376 GHz)
Half-Power (-3 dB) Bandwidth	50.14 MHz	320.5 MHz	57.13 MHz	246.9 MHz
Directivity	4.550 dBi	5.861 dBi	6.013 dBi	6.511 dBi
Gain (IEEE)	-5.879 dB	3.537 dB	-1.469 dB	2.447 dB
Realized Gain	-5.882 dB	3.505 dB	-1.512 dB	1.945 dB
Half-Power Beamwidth (HPBW)	95.3 deg	91.9 deg	55.4 deg	116.6 deg
Front-to-Back Ratio	3.056 dB	9.642 dB	15.758 dB	28.125 dB

Table 2: Result Summary for UHF and S-Band Patch Antennas on Full CubeSat structure

PARAMETER	Comms Patch antennas added to Full CubeSat structure (No Wire antennas)		Comms Patch antennas added to Full CubeSat structure (Wires not Energized)	
	UHF Antenna	S-Band Antenna	UHF Antenna	S-Band Antenna
Input Reflection Coefficient (S11 Parameter)	-24.347 dB (at 912 MHz)	-11.265 dB (at 2.373 GHz)	-25.553 dB (at 912 MHz)	-11.167 dB (at 2.376 GHz)
Half-Power (-3 dB) Bandwidth	55.66 MHz	253.5 MHz	54.41 MHz	252.9 MHz
Directivity	4.699 dBi	6.368 dBi	5.705 dBi	11.12 dBi
Gain (IEEE)	-3.938 dB	2.369 dB	-3.526 dB	6.920 dB
Realized Gain	-3.971 dB	1.872 dB	-3.550 dB	6.435 dB
Half-Power Beamwidth (HPBW)	164.2 deg	116.4 deg	47.1 deg	11 deg
Front-to-Back Ratio	15.031 dB	27.66 dB	14.885 dB	32.576 dB

In comparison to the results previously reported, with only one side of the CubeSat structure and both patch antennas added to it (Table **1**), the directivity and realized gain obtained in the first simulation stage (Section I.) for the UHF antenna present a significant decrease, from 6.013 dBi to 4.699 dBi and from -1.469 dB to -3.938 dB respectively (Table **2** and Figures **1.5** to **1.8**). This is probably due to interference with the rest of the CubeSat metallic structure. Also, there is a slight change in the behaviour of the radiation pattern for the UHF patch, with respect to the previous report, where there's no apparent sidelobes towards the main direction of the antenna. The S-band patch is not heavily affected by the complete CubeSat structure (Figures **1.9** to **1.12**), however the small interference between the UHF patch and the S-band patch is still present.

Adding the 2.4m Wire antennas at the front of the Cube structure (Simulation stage - Section II.), once again shows the interference effect they produce on the behaviour of the radiation pattern for both UHF and S-band patch antennas. Particularly the effect in the UHF pach antenna is visible on the directivity level, the direction shift and "irregular" shape of the main lobe and the Half-Power Beamwidth (HPBW) change from 164 to 47 degrees (Figures **2.5** to **2.7**). In the case of the S-Band patch, the interference caused by the wire antennas produces a considerable enhancement in directivity and realized gain along with a narrowing of the main lobe, from 116.4 degrees to only 11 degrees (Figures **2.9** to **2.12**).