S-BAND PATCH ANTENNA DESIGN 1

1. ***Patch Antenna Design:*** S-Band square/rectangular patch antenna, for operation at 2.4GHz. Simulations performed with CST Studio Suite 2017 ©. Antenna design consists of a FR4 substrate with 1.0mm thickness, and double copper layer, where the patch antenna is on the board's top layer, and bottom layer works as ground plane. Feeding Input port located at the edge of the patch (Red point, figure 1.1).

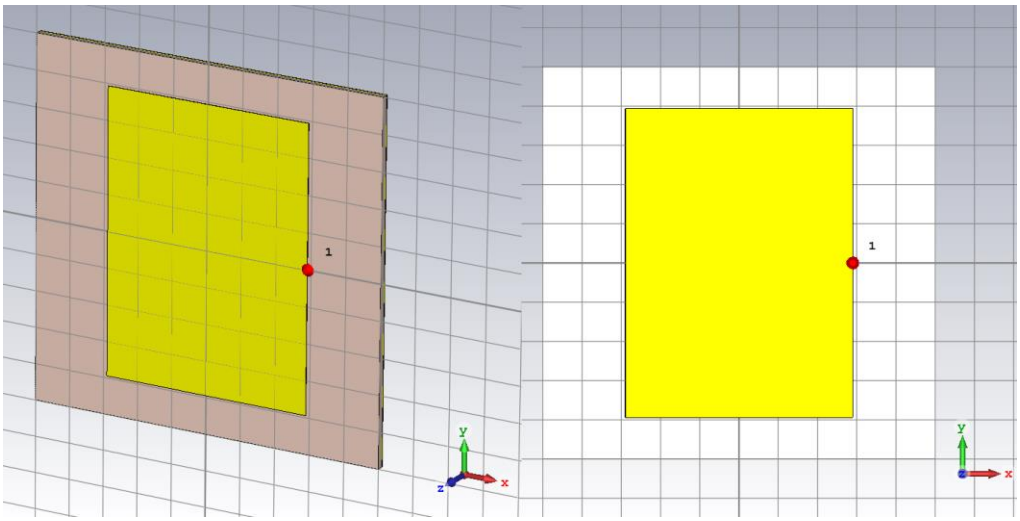

Figure 1.1. Patch Design. Perspective and Frontal Views

Name	Expression	Value	Description	Type
f	= 2.4	2.4	Frequency [GHz]	Frequency
Lambda	= 125	125	Wavelength [mm]	Length
LambdaG	= 61.808	61.808	Guided Wavelength [mm]	Length
Lpatch	= 28.973	28.973	Patch Length (X Axis) [mm]	Length
Lsubs	= 50	50	Substrate Length (X Axis) [mm]	Length
Tpatch	= 0.05	0.05	Patch Thickness (Z Axis) [mm]	Length
Tsubs	= 1	1	Substrate Thickness (Z Axis) [mm]	Length
Wpatch	= 39.393	39.393	Patch Width (Y Axis) [mm]	Length
Wsubs	= Lsubs	50	Substrate Width (Y Axis) [mm]	Length

Figure 1.2. Parameter List for S-Band Patch Antenna

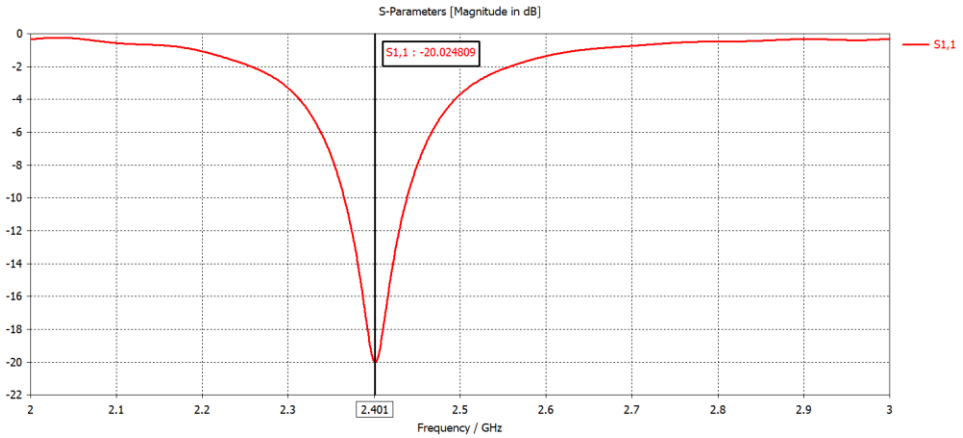

Figure 1.3. Input reflection coefficient (S11 Parameter) for S-Band Patch Antenna

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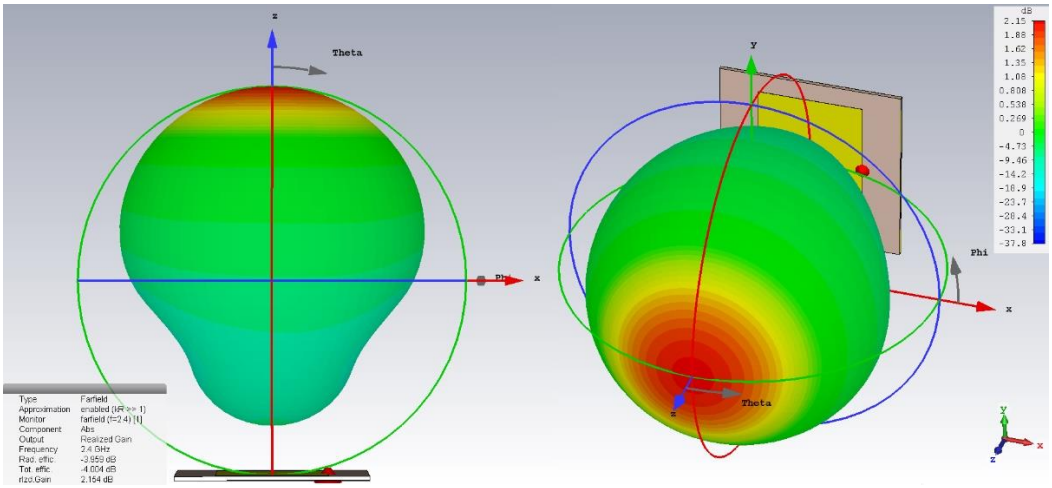

Figure 1.4. Far-field Radiation Pattern for Patch Antenna Design. Realized Gain.

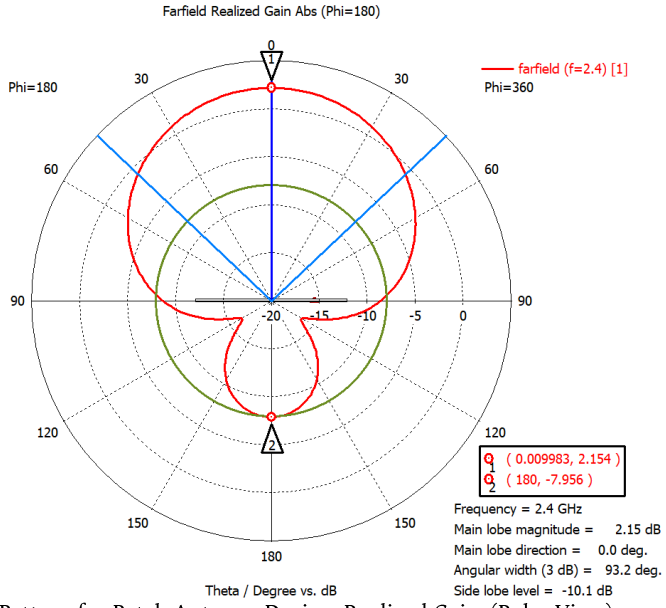

Figure 1.5. Far-field Radiation Pattern for Patch Antenna Design. Realized Gain. (Polar View)

PARAMETER	RESULT
Input Reflection Coefficient (S11 Parameter)	-20.024 dB (at 2.401 GHz)
Directivity	6.157 dBi
Gain (IEEE)	2.198 dB
Realized Gain	2.154 dB
Front-to-Back Ratio	10.11

Table 1.1. Results Summary.

2. ***Patch Antenna added to CubeSat structure:*** S-Band square/rectangular patch antenna, for operation at 2.4GHz, added at Left- and Right-side of CubeSat structure. Design step performed without CubeSat panels or 2.4 m Wire Antennas. Simulations performed with CST Studio Suite 2017 ©.

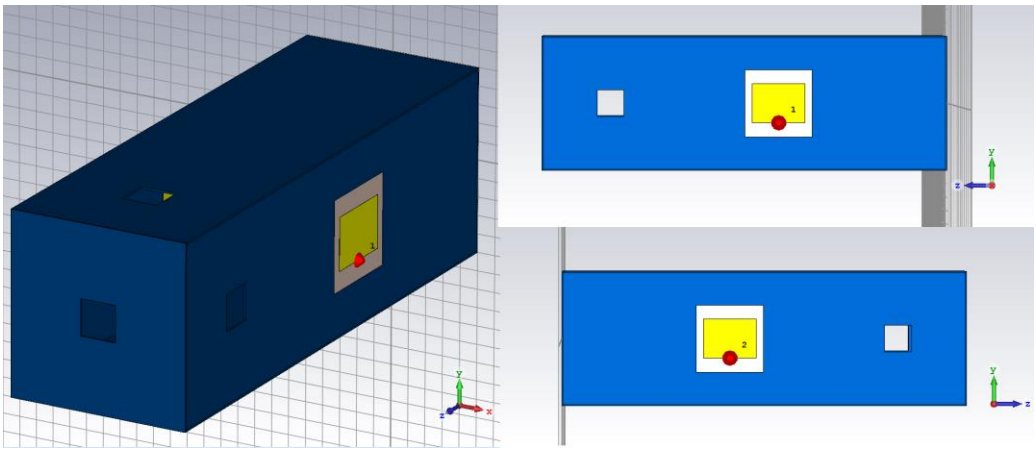

Figure 2.1. Antenna Design added to structure. Perspective, Left-Side and Right-Side Views

Name	Expression	Value	Description	Type
f	2.4	2.4	Frequency [GHz]	Frequency
Gpatch	10	10	Distance From Box Edge to Patch [cm]	Length
Hbox	10	10	Box Height (Y Axis) [cm]	Length
Lambda	12.5	12.5	Wavelength [cm]	Length
LambdaG	6.1808	6.1808	Guided Wavelength [cm]	Length
Lbox	30	30	Box Length (Z Axis) [cm]	Length
Lpatch	2.8973	2.8973	Patch Length (Y Axis) [cm]	Length
Lsubs	5	5	Substrate Length (Y Axis) [cm]	Length
Tbox	0.1	0.1	Box Thickness [cm]	Length
Tpatch	0.005	0.005	Patch Thickness (X Axis) [cm]	Length
Tsubs	Tbox	0.1	Substrate Thickness (X Axis) [cm]	Length
Wpatch	3.9393	3.9393	Patch Width (Z Axis) [cm]	Length
Wsubs	Lsubs	5	Substrate Width (Z Axis) [cm]	Length

Figure 2.2. Parameter List for S-Band Patch Antenna

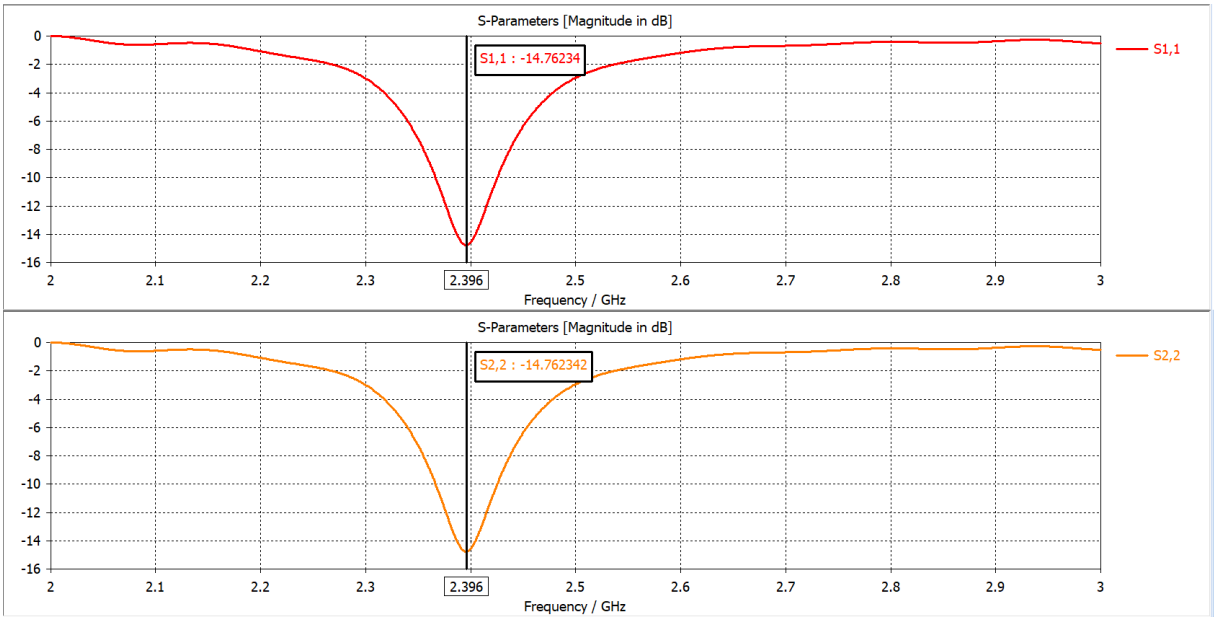

Figure 2.3. Input reflection coefficients (S11 and S22 Parameters) for both S-Band Patch Antennas

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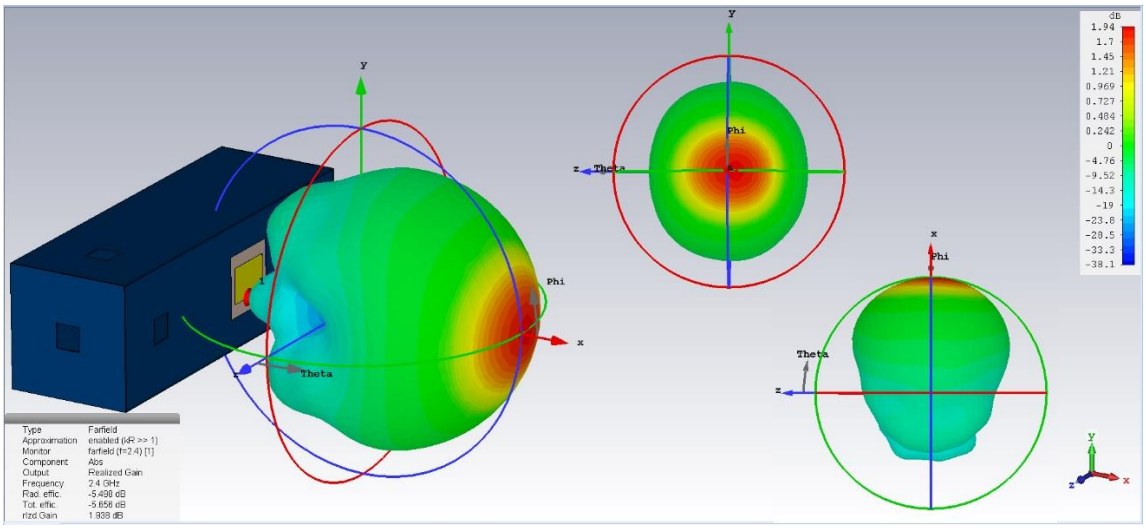

Figure 2.4. Far-field Radiation Pattern for Left-Side Patch Antenna Design. Realized Gain.

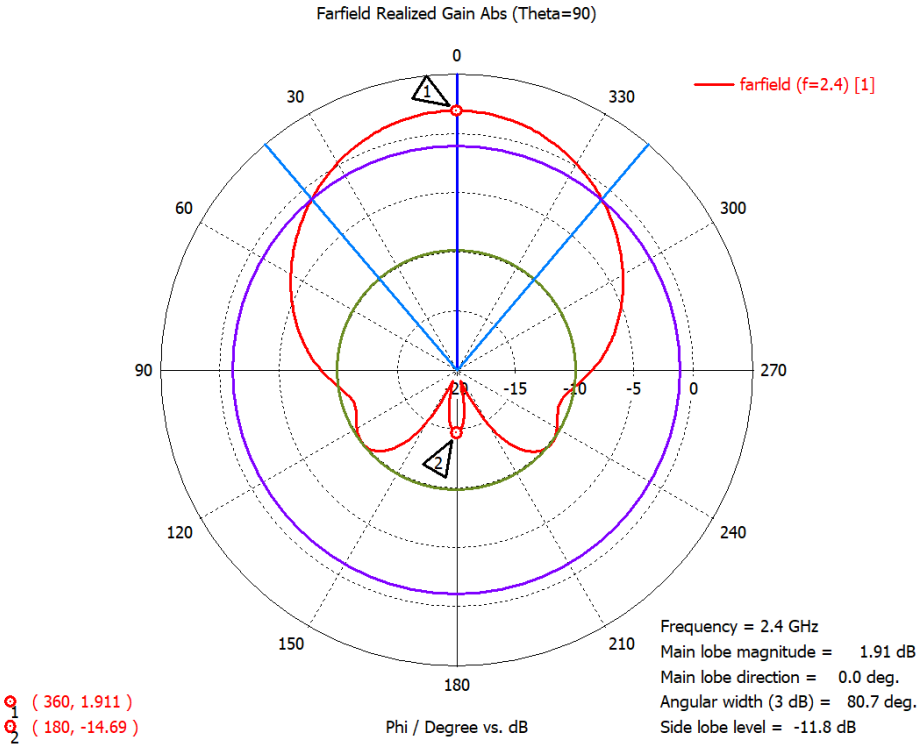

Figure 2.5. Far-field Radiation Pattern for Left-Side Patch Antenna Design. Realized Gain. (Polar View)

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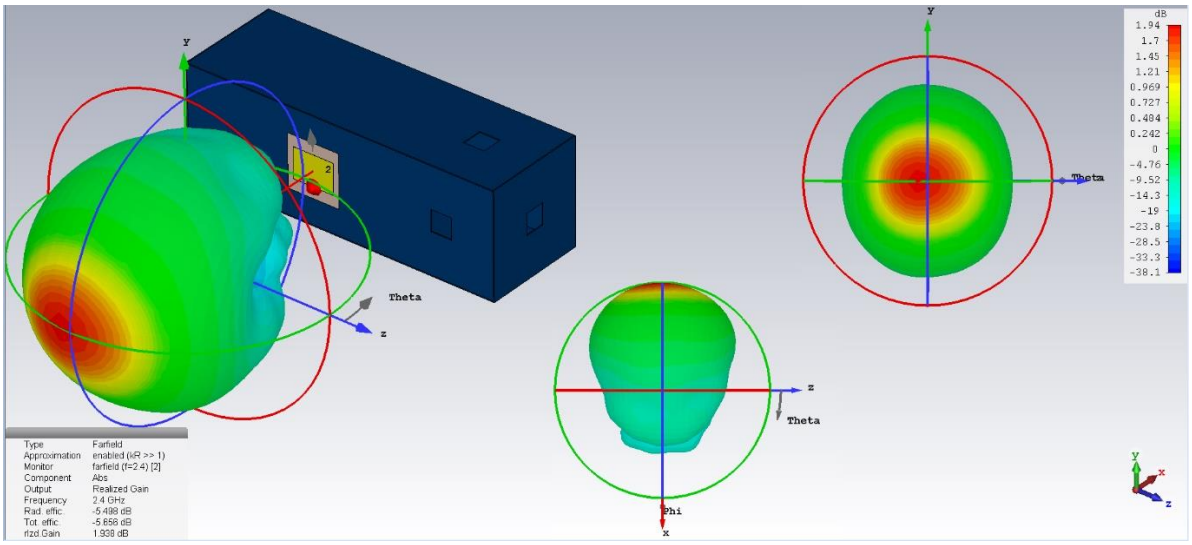

Figure 2.6. Far-field Radiation Pattern for Right-Side Patch Antenna Design. Realized Gain.

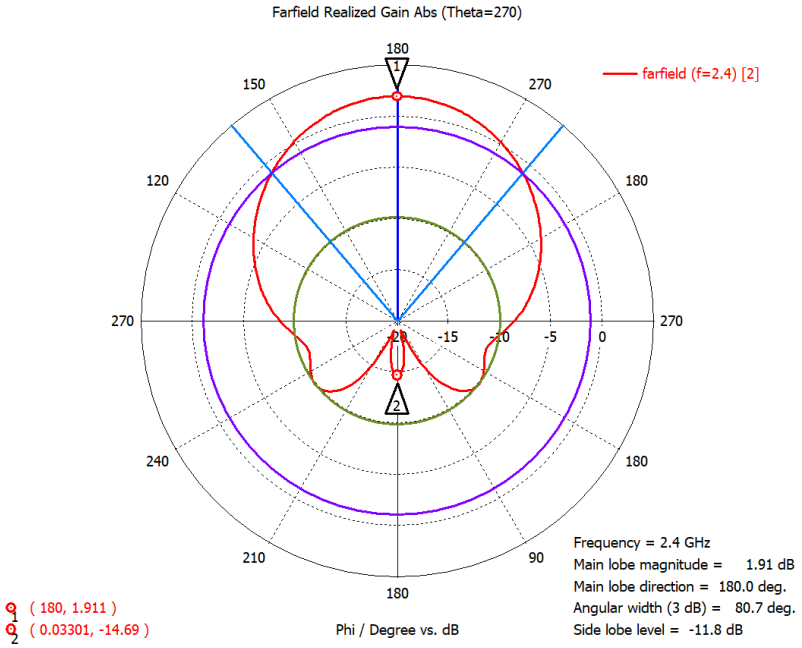

Figure 2.7. Far-field Radiation Pattern for Right-Side Patch Antenna Design. Realized Gain. (Polar View)

PARAMETER	Left-Side Patch	Right-Side Patch
Input Reflection Coefficient (S11 Parameter)	-14.762 dB (at 2.396 GHz)	-14.762 dB (at 2.396 GHz)
Directivity	7.594 dBi	7.594 dBi
Gain (IEEE)	2.096 dB	2.096 dB
Realized Gain	1.938 dB	1.938 dB
Front-to-Back Ratio	16.601	16.601

Table 2.1. Results Summary.

3. ***Back Panels added to CubeSat structure*:** S-Band square/rectangular patch antenna, for operation at 2.4GHz, added at Left- and Right-side of CubeSat structure. Design step performed adding CubeSat back panels, without 2.4 m Wire Antennas. Simulations performed with CST Studio Suite 2017 ©.

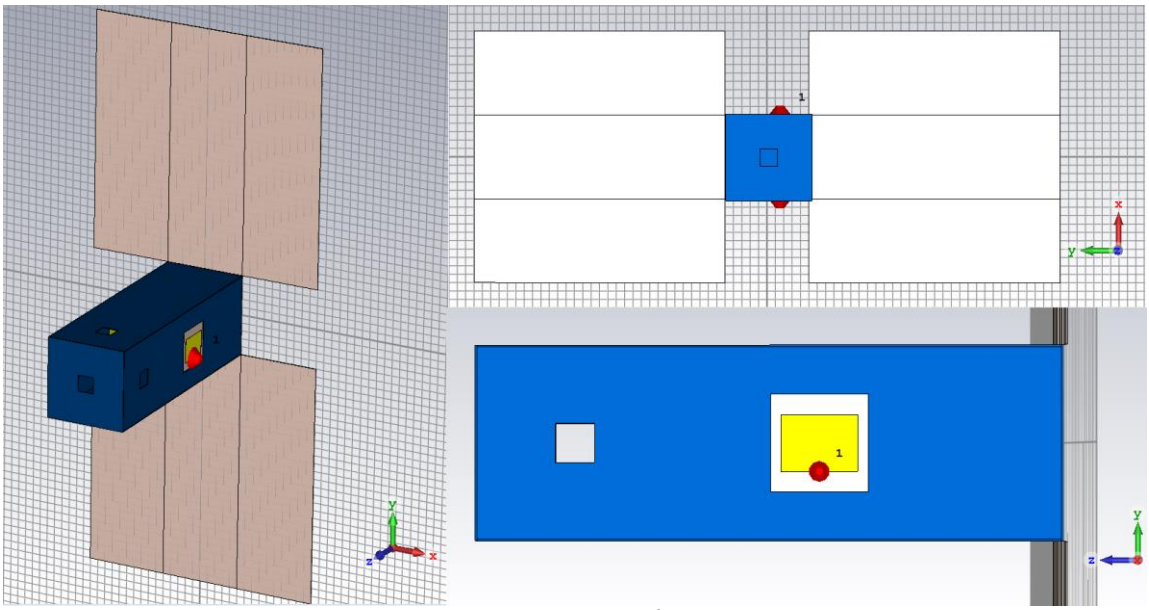

Figure 3.1. Back Panels added to structure. Perspective, Front and Left-Side Views

Name	Expression	Value	Description	Type
f	2.4	2.4	Frequency [GHz]	Frequency
Gpatch	10	10	Distance From Box Edge to Patch [cm]	Length
Hbox	10	10	Box Height (Y Axis) [cm]	Length
Hpan	10	10	Panel Height/Width (X Axis) [cm]	Length
Lambda	12.5	12.5	Wavelength [cm]	Length
LambdaG	6.1808	6.1808	Guided Wavelength [cm]	Length
Lbox	30	30	Box Length (Z Axis) [cm]	Length
Lpan	30	30	Panel Length (Y Axis) [cm]	Length
Lpatch	2.8973	2.8973	Patch Length (Y Axis) [cm]	Length
Lsubs	5	5	Substrate Length (Y Axis) [cm]	Length
MPHole	2	2	Wire Antenna Box Hole	Length
Tbox	0.1	0.1	Box Thickness [cm]	Length
Tpan	0.08	0.08	Panel Thickness [cm]	Length
Tpatch	0.005	0.005	Patch Thickness (X Axis) [cm]	Length
Tsubs	Tbox	0.1	Substrate Thickness (X Axis) [cm]	Length
Wpatch	3.9393	3.9393	Patch Width (Z Axis) [cm]	Length
Wposc	Hbox/2	5	Wire Antena Central Position [cm]	Length
Wsubs	Lsubs	5	Substrate Width (Z Axis) [cm]	Length

Figure 3.2. Parameter List for CubeSat structure and S-Band Patch Antenna design

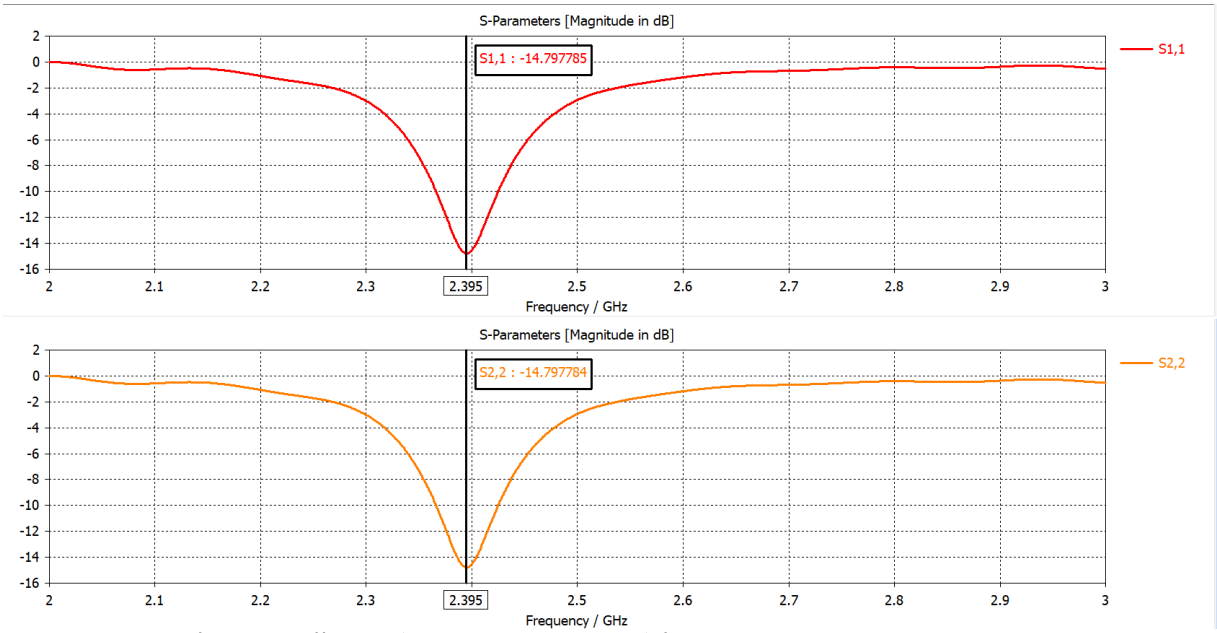

Figure 3.3. Input reflection coefficients (S11 and S22 Parameters) for both S-Band Patch Antennas

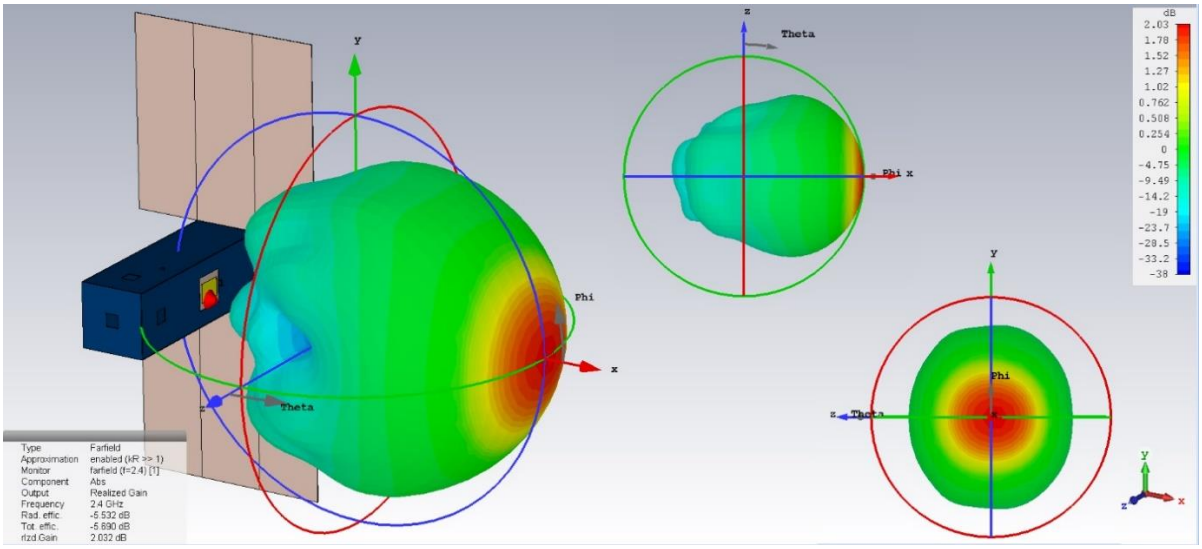

Figure 3.4. Far-field Radiation Pattern for Left-Side Patch Antenna Design. Realized Gain.

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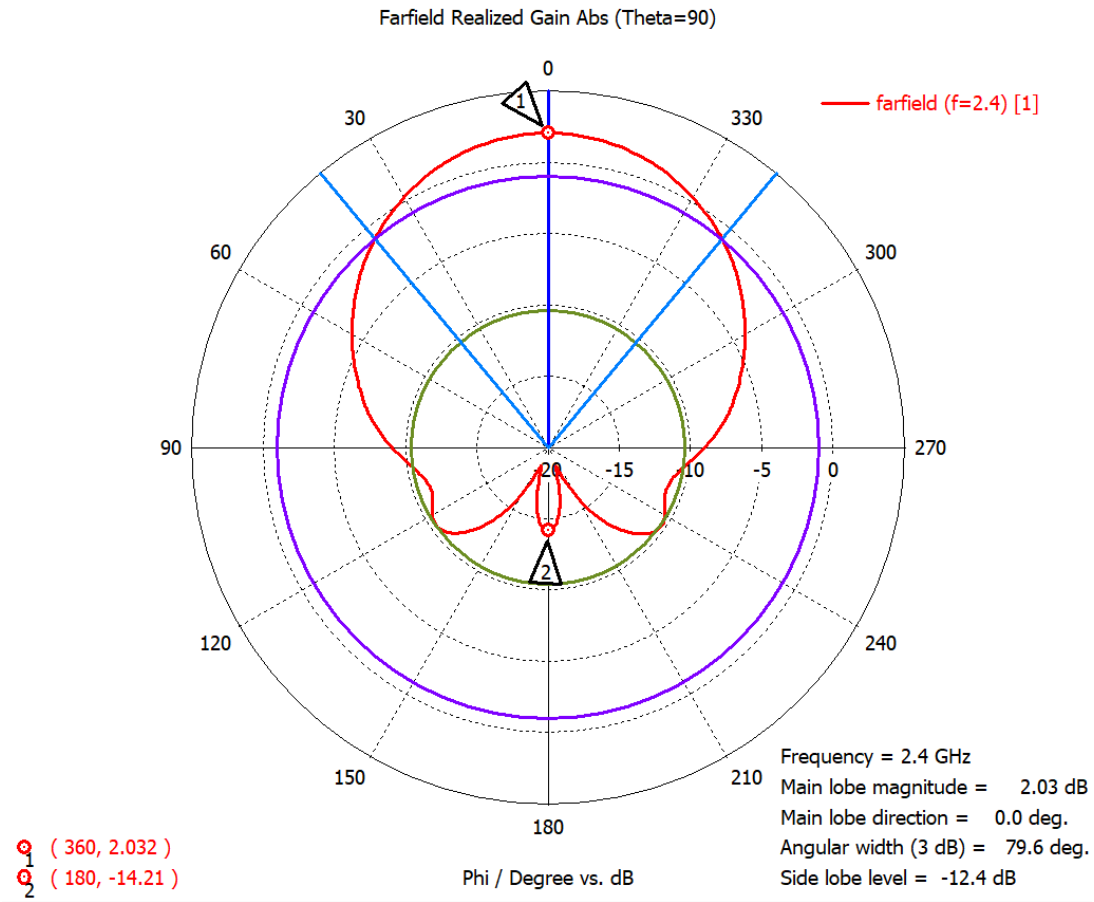

Figure 3.5. Far-field Radiation Pattern for Left-Side Patch Antenna Design. Realized Gain. (Polar View)

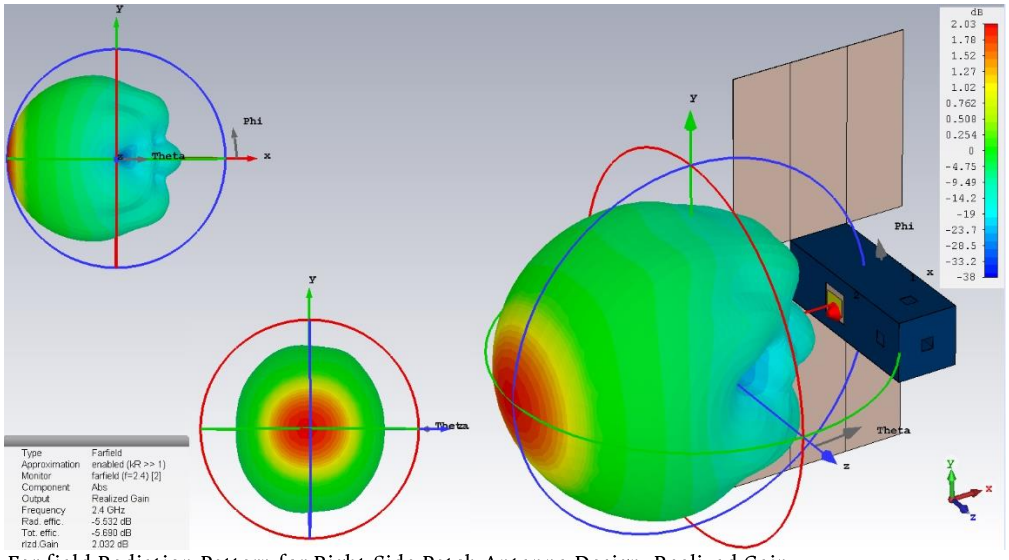

Figure 3.6. Far-field Radiation Pattern for Right-Side Patch Antenna Design. Realized Gain.

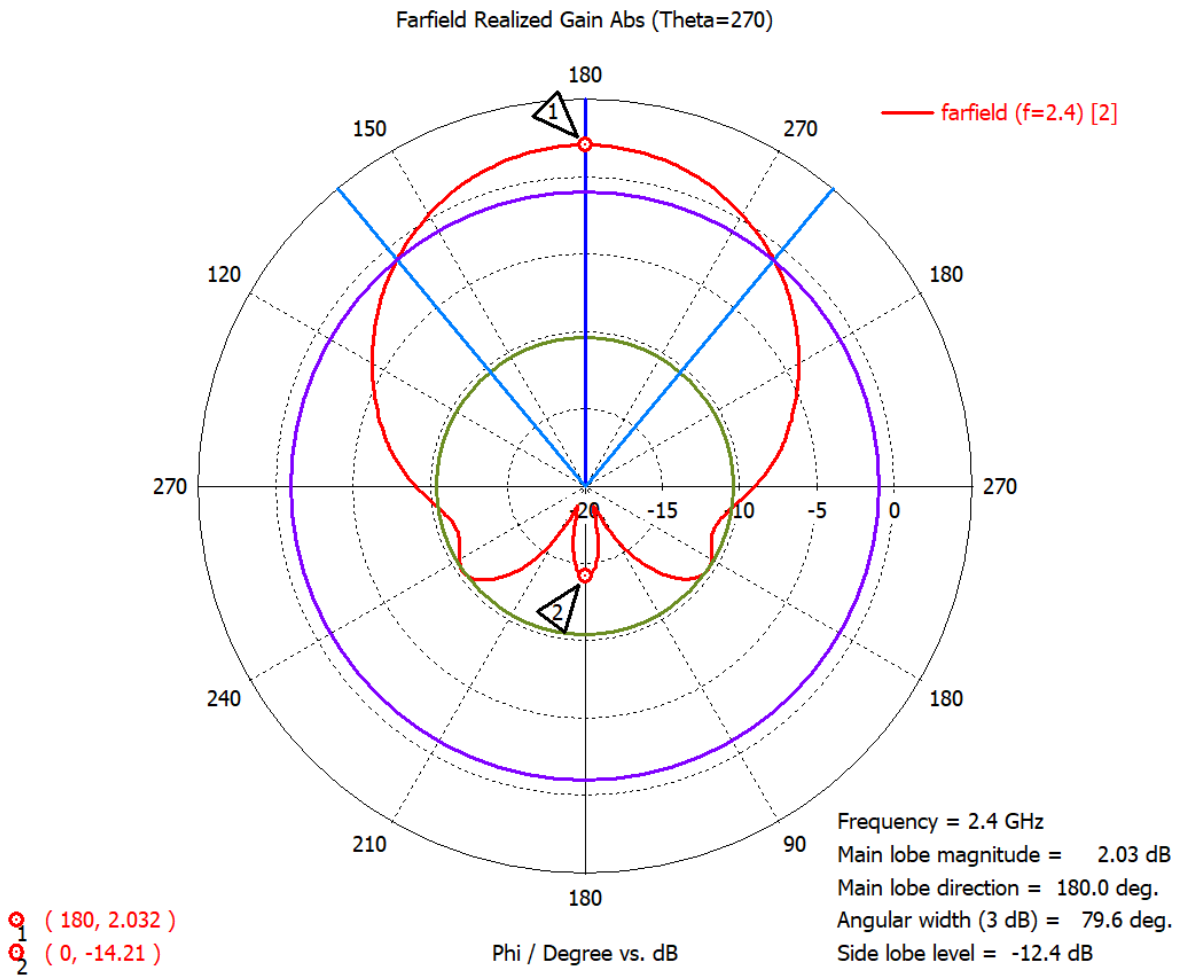

Figure 3.7. Far-field Radiation Pattern for Right-Side Patch Antenna Design. Realized Gain. (Polar View)

PARAMETER	Left-Side Patch	Right-Side Patch
Input Reflection Coefficient (S11 Parameter)	-14.797 (at 2.395 GHz)	-14.797 (at 2.395 GHz)
Directivity	7.722 dBi	7.722 dBi
Gain (IEEE)	2.190 dB	2.190 dB
Realized Gain	2.032 dB	2.032 dB
Front-to-Back Ratio	16.232	16.232

Table 3.1. Results Summary.

4. ***2.4m Wire Antennas added to CubeSat structure:*** S-Band square/rectangular patch antenna, for operation at 2.4GHz, added at Left- and Right-side of CubeSat structure. Design step performed

adding CubeSat back panels and 2.4 m Wire Antennas. At this stage, Wire antennas are not yet energized. Simulations performed with CST Studio Suite 2017 ©.

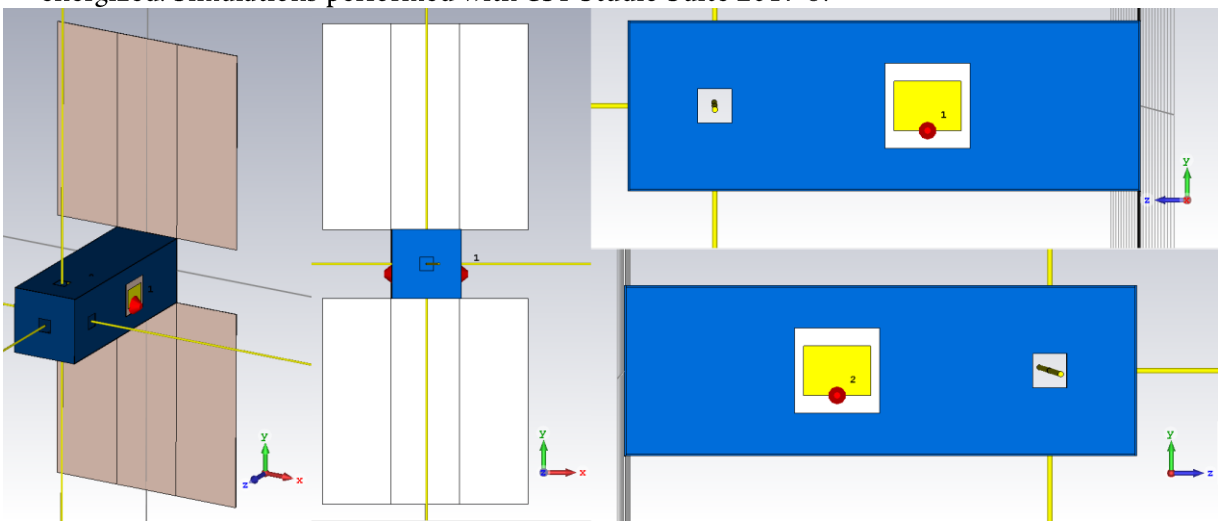

Figure 4.1. Wire Antennas added to structure. Perspective, Front and Side Views

Name	Expression	Value	Description	Type
f	2.4	2.4	Frequency [GHz]	Frequency
Gpatch	10	10	Distance From Box Edge to Patch [cm]	Length
Hbox	10	10	Box Height (Y Axis) [cm]	Length
Hpan	10	10	Panel Height/Width (X Axis) [cm]	Length
Lambda	12.5	12.5	Wavelength [cm]	Length
LambdaG	6.1808	6.1808	Guided Wavelength [cm]	Length
Lbox	30	30	Box Length (Z Axis) [cm]	Length
Lpan	30	30	Panel Length (Y Axis) [cm]	Length
Lpatch	2.8973	2.8973	Patch Length (Y Axis) [cm]	Length
Lsubs	5	5	Substrate Length (Y Axis) [cm]	Length
MPHole	2	2	Wire Antenna Box Hole	Length
Tbox	0.1	0.1	Box Thickness [cm]	Length
Tpan	0.08	0.08	Panel Thickness [cm]	Length
Tpatch	0.005	0.005	Patch Thickness (X Axis) [cm]	Length
Tsubs	Tbox	0.1	Substrate Thickness (X Axis) [cm]	Length
Wpatch	3.9393	3.9393	Patch Width (Z Axis) [cm]	Length
Wposc	Hbox/2	5	Wire Antena Central Position [cm]	Length
Wsubs	Lsubs	5	Substrate Width (Z Axis) [cm]	Length
Lwire	240	240	Wire Antenna Length [cm]	Length
Rwire	0.16	0.16	Wire Antenna Radius [cm]	Length

Figure 4.2. Parameter List for Structure design

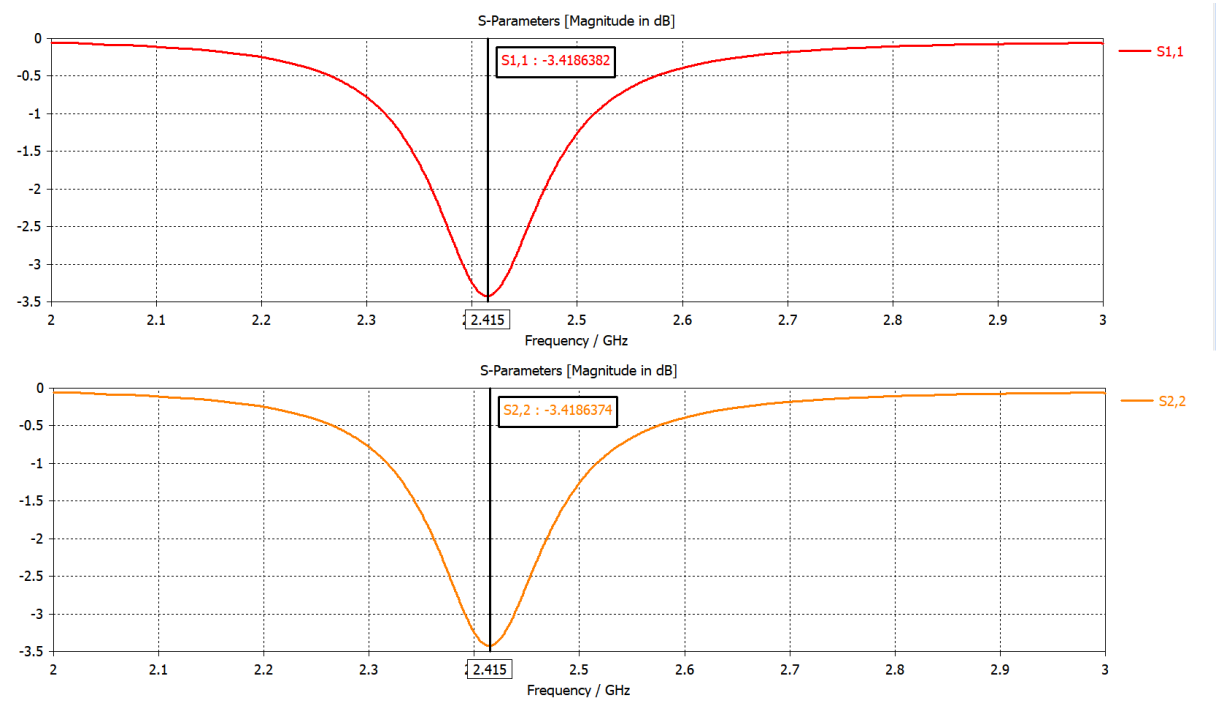

Figure 4.3. Input reflection coefficients (S11 and S22 Parameters) for both S-Band Patch Antennas

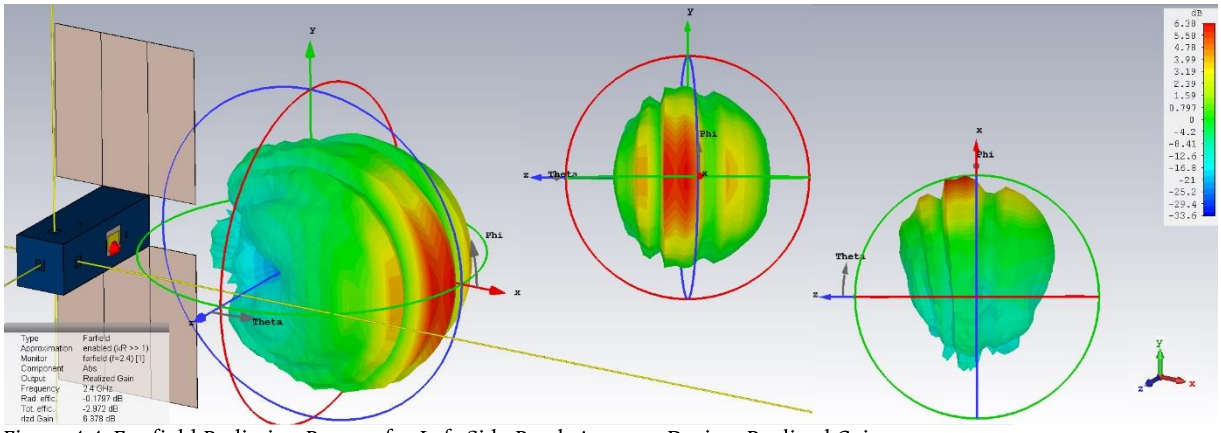

Figure 4.4. Far-field Radiation Pattern for Left-Side Patch Antenna Design. Realized Gain.

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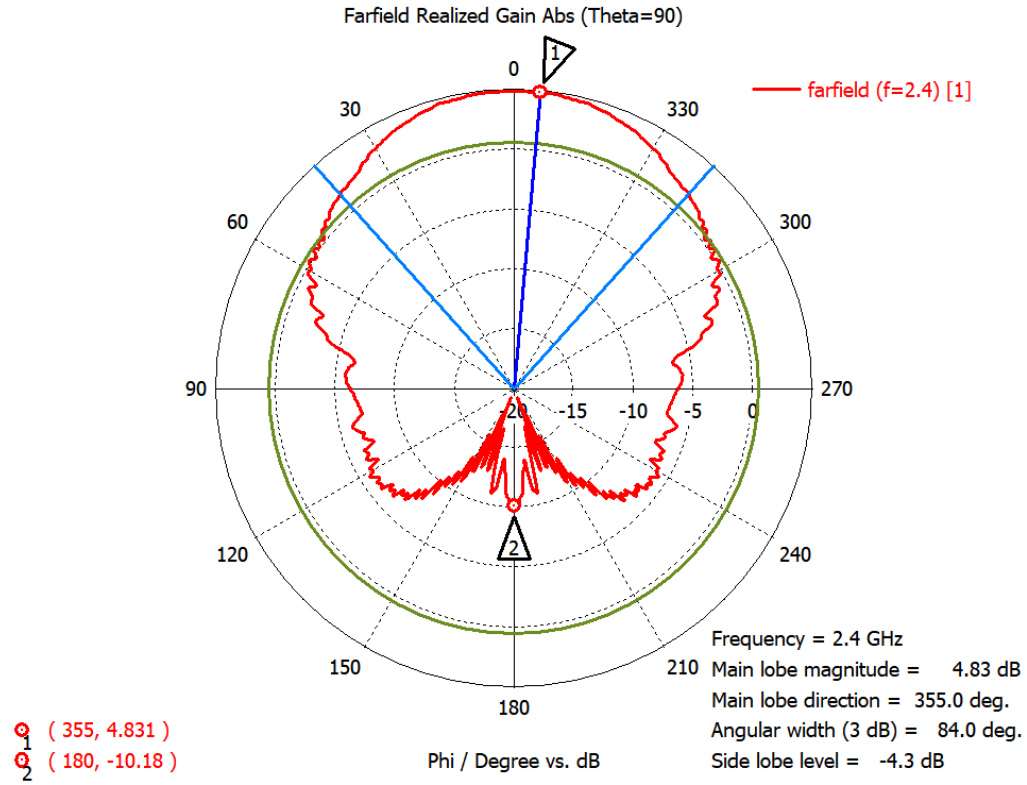

Figure 4.5. Far-field Radiation Pattern for Left-Side Patch Antenna Design. Realized Gain. (Polar View)

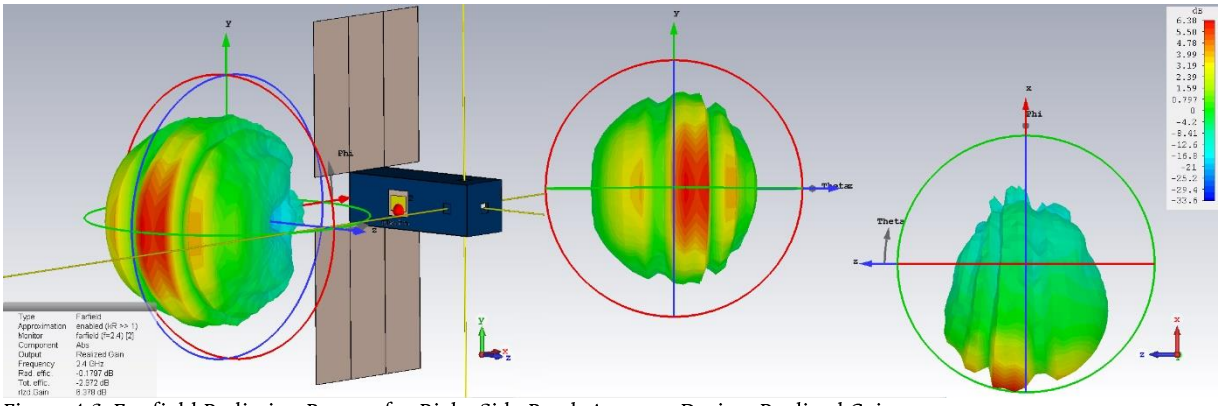

Figure 4.6. Far-field Radiation Pattern for Right-Side Patch Antenna Design. Realized Gain.

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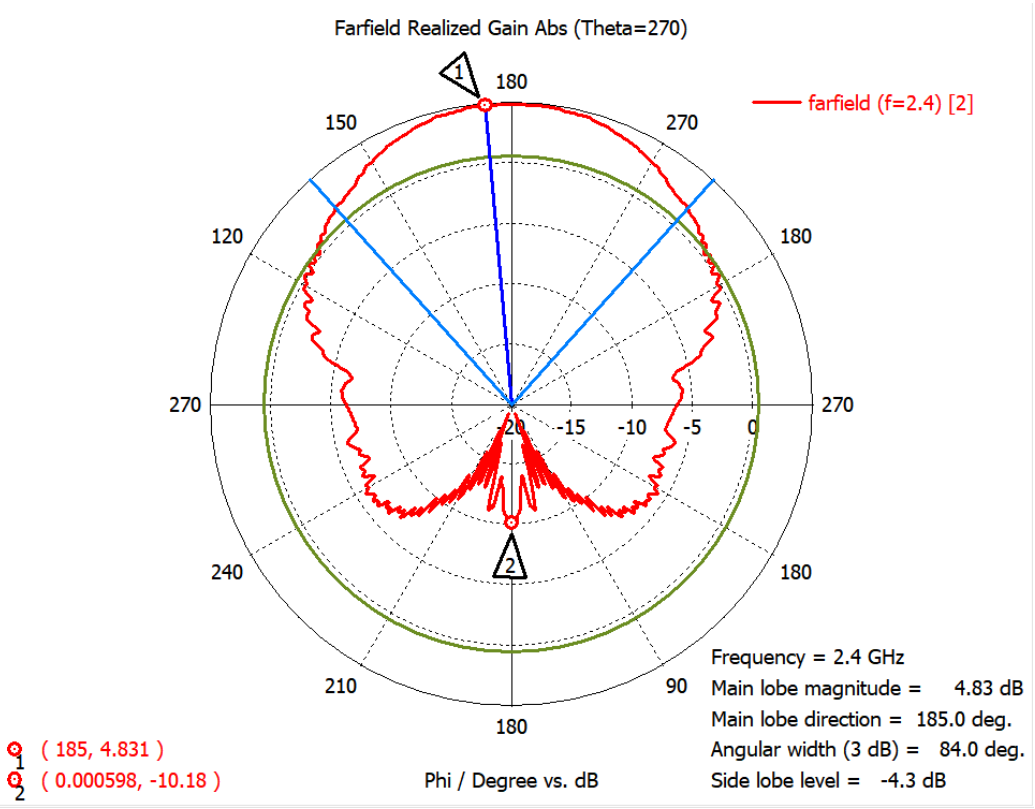

Figure 4.7. Far-field Radiation Pattern for Right-Side Patch Antenna Design. Realized Gain. (Polar View)

PARAMETER	Left-Side Patch	Right-Side Patch
Input Reflection Coefficient (S11 Parameter)	-3.4186(at 2.415 GHz)	-3.4186(at 2.415 GHz)
Directivity	9.350 dBi	9.350 dBi
Gain (IEEE)	9.170 dB	9.170 dB
Realized Gain	6.378 dB	6.378 dB
Front-to-Back Ratio	15.011	15.011

Table 4.1. Results Summary.

***Pending: Simulation results energizing all 3 wire antennas.**

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