Universidad Nacional de Frontera
Sullana - Piura

VI Jornada Internacional de Ciencias Avanzadas – Astrodinámica y Teledetección 2026

DESIGN OF MICROSTRIP ANTENNA ARRAY AT C-BAND FOR CUBESAT

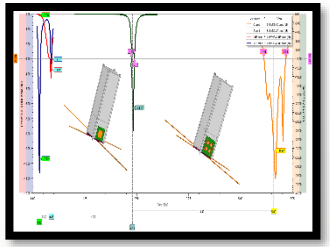
Lic. en Física Vladimir Adolfo Juarez Ortiz
MEng. Space technology and Application

AGENDA

1.

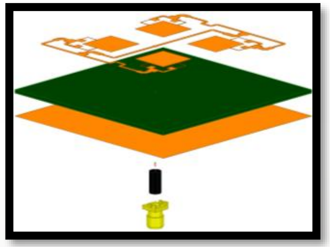
TECHNOLOGY CUBESAT

2.



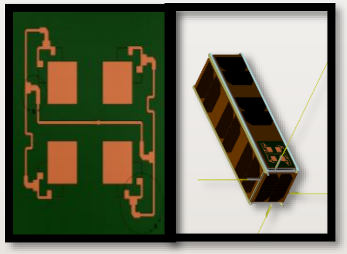
ANTENNAS SYSTEM

3.



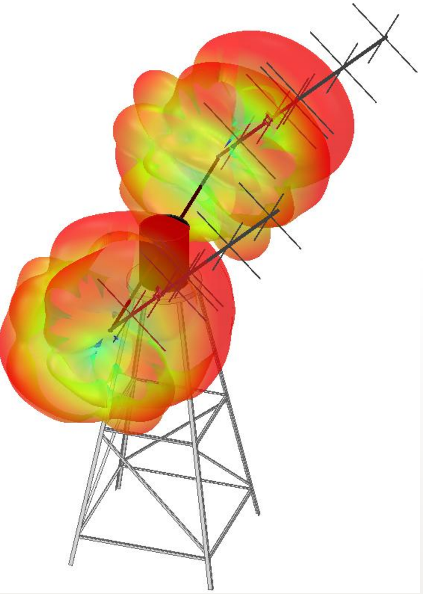
MICROSTRIP ANTENNA

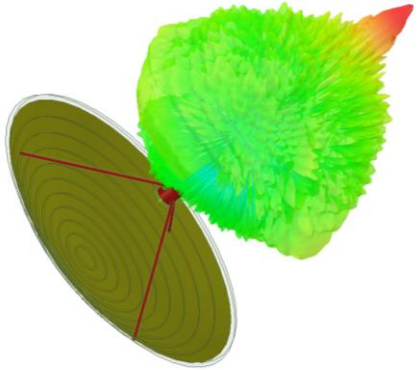
4.



PROPOSAL ANTENNA DESIGN

TECHNOLOGY CUBESATS

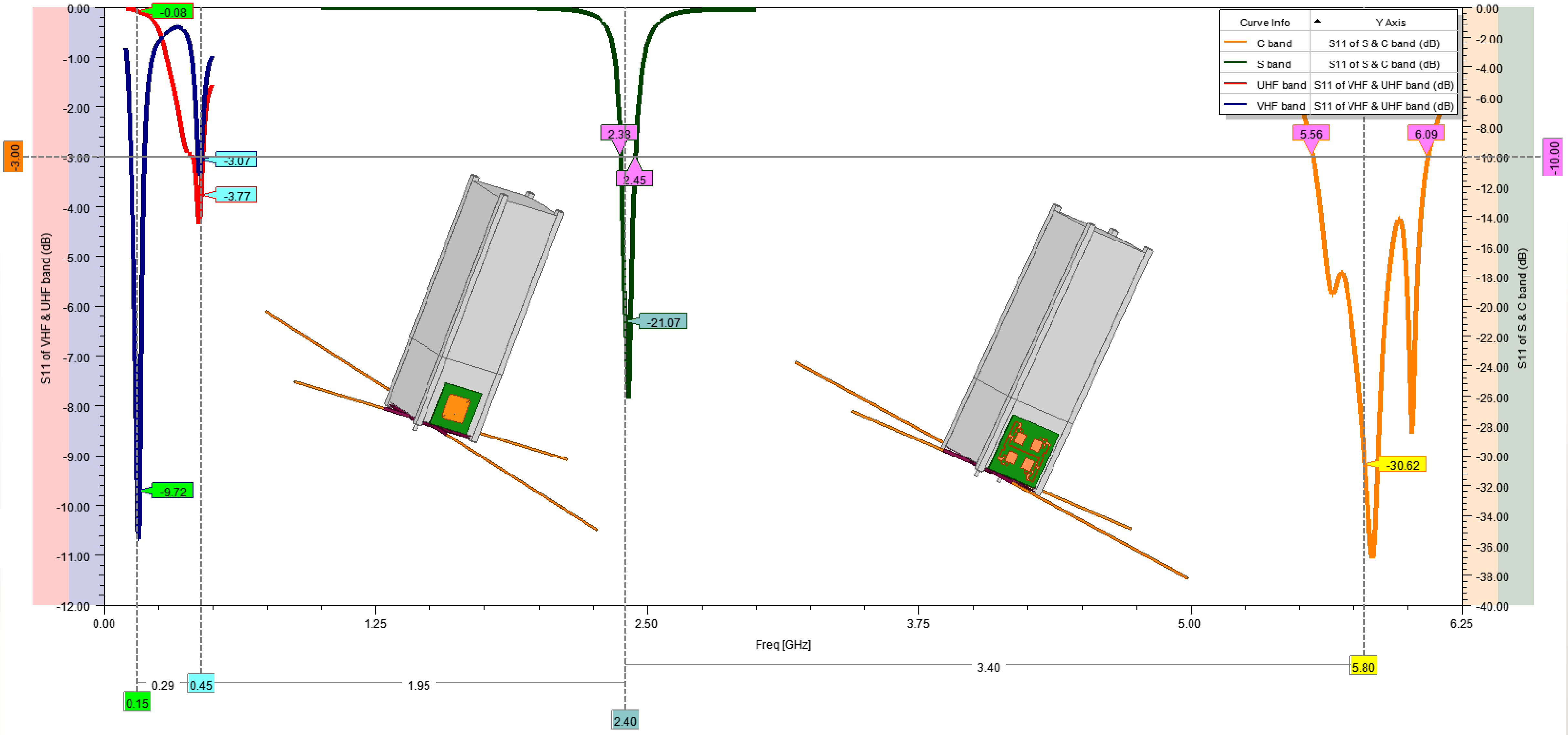




FUNDAMENTAL LIMITS IN ANTENNAS FOR CUBESAT

- Trade off in:
    - size,
    - bandwidth,
    - axial ratio,
    - VSWR and
    - frequency of operation
- To add more sensors is currently a common idea in all CubeSats project
- To transmitter a lot of data from sensors will need to use bigger antennas
- Antennas with higher frequency cannot be arbitrary small
- CubeSat structure is small to assembly bigger antennas

ANTENNAS AT CUBESAT

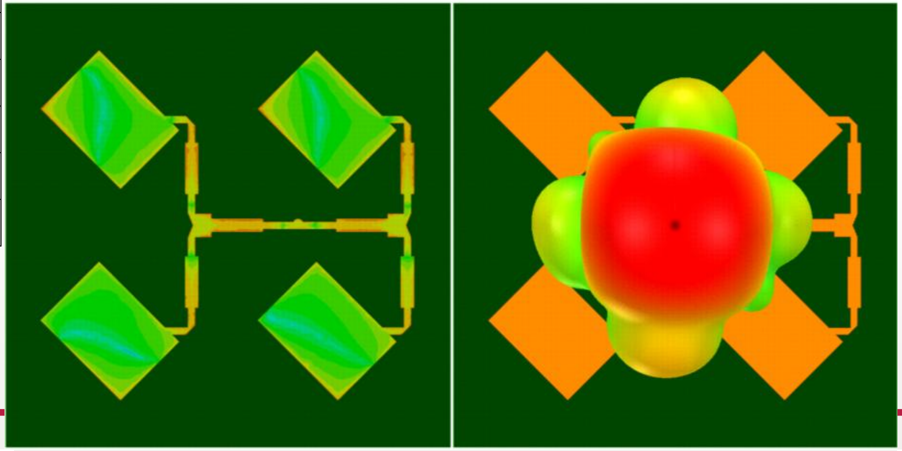


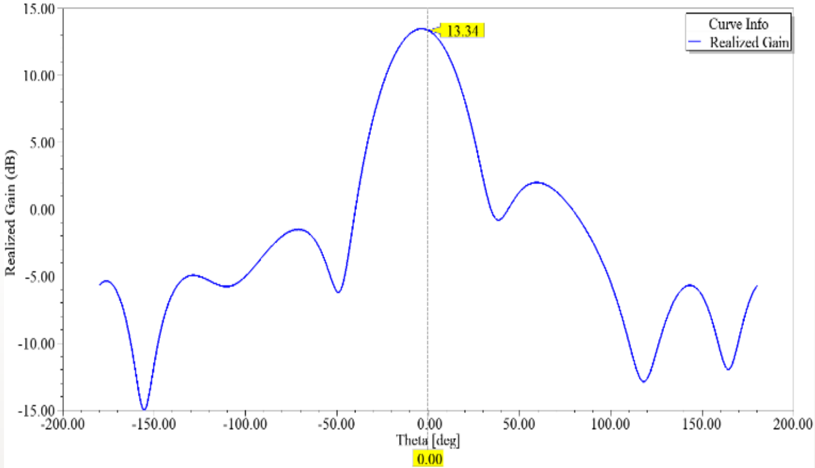
LITERATURE REVIEW

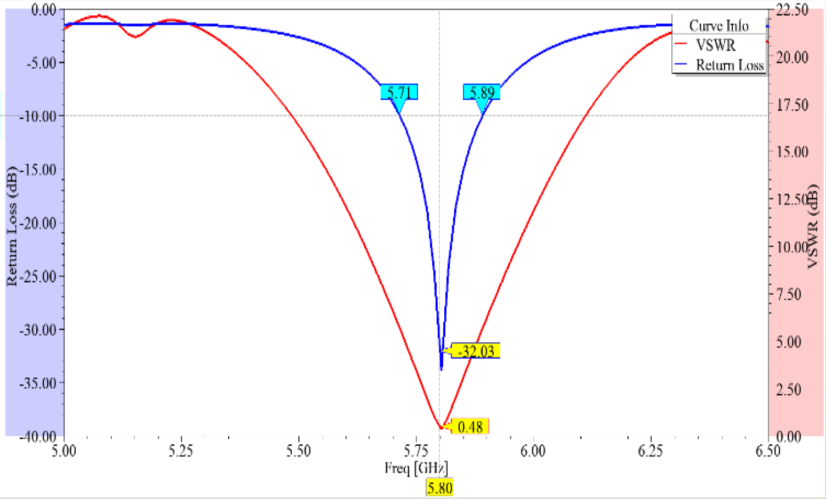
V. A. Juarez-Ortiz and R. Perea-Tamayo, "Design of a C-band high gain microstrip antenna array for CubeSat standard," in IEEE MTT-S Int. Microw. Symp. Dig., Arequipa, Peru, Dec. 2018, pp. 1–3.

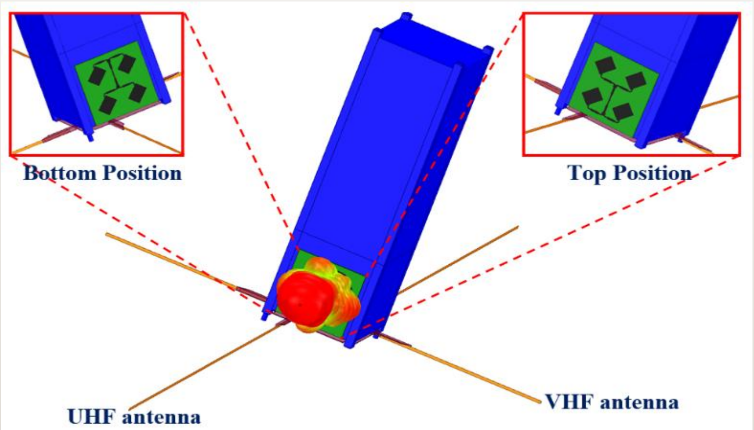
Characteristics of RT/Duroid® 6002 Substrate

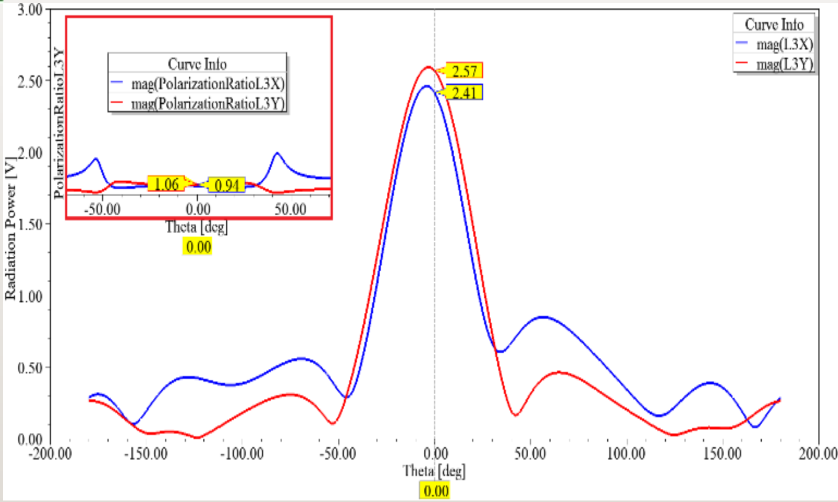
Substrate Characteristics		Value	Unit
Dielectric Constant		2.94	-
Dissipation Factor (tan α)		0.0012	-
Thickness	Substrate	1.524	mm
	Copper	0.035	mm
	Ground	0.035	mm
Dimensions		74 x 74	mm





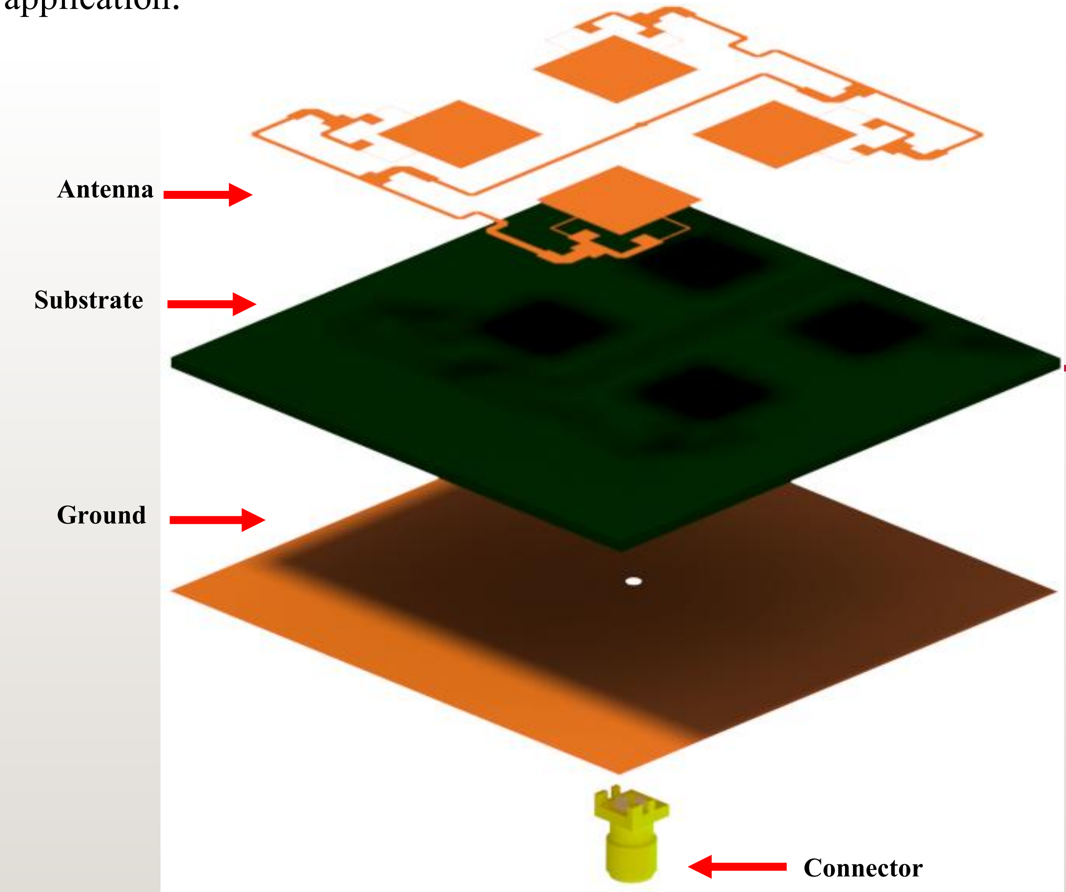






MICROSTRIP ANTENNA

Is a small antenna conformed for two parallel conductors that are separated for a thin dielectric substrate of dielectric permittivity ($\in_r$) and thickness (h). A ground plane in the bottom and radiating patch in the top (antenna), microstrip antennas nowadays are used in different application as CubeSat, microwave, satellite communications, missiles, mobile phones, and another microwaves application.



Line Model, in this model the microstrip antenna is represented as two slots of width ΔL and height W that are separated by a transmission line of length L and that is open circuited at both the ends. As a result of this in the width of the patch is experimented a voltage maximum and current is a minimum.

$$\in_{eff}=\frac{\in_r+1}{2}+\frac{\in_r+1}{2}\left[1+12*\frac{h}{W}\right]^{-\frac{1}{2}}$$

$$W=\frac{c}{2*f}\sqrt{\frac{2}{\in_r+1}}$$

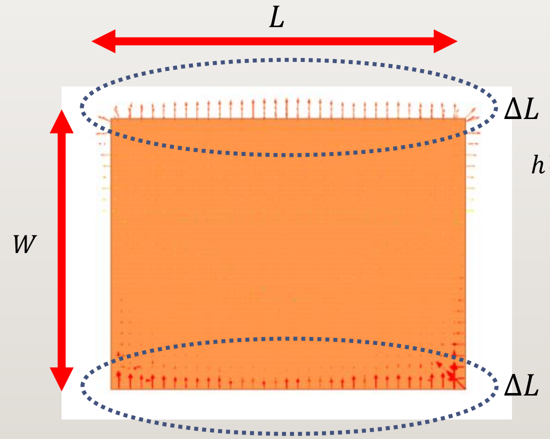
$$\Delta L=0.412*h*\frac{(\in_{eff}+0.3)*(\frac{W}{h}+0.264)}{(\in_{eff}+0.258)*(\frac{W}{h}+0.8)}$$

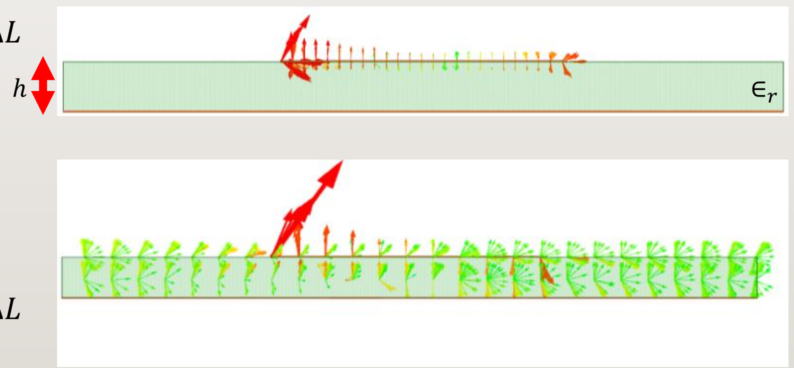
c= Velocity of the light

f= Frequency of resonance

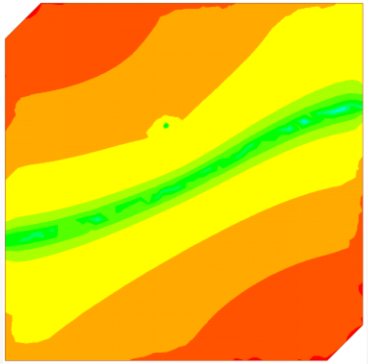
Cavity model, is to provide the different of radiation mechanism, so that mathematical equations are development for both electric and magnetic fields, therefore the microstrip antenna is represented as a cavity that is dielectrically loaded.

$$L=\frac{c}{2*f*\sqrt{\in_{eff}}}-2*\Delta L$$

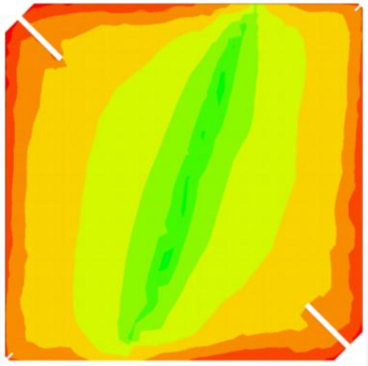




METHOD TO GET CIRCULAR POLARIZATION



LHCP

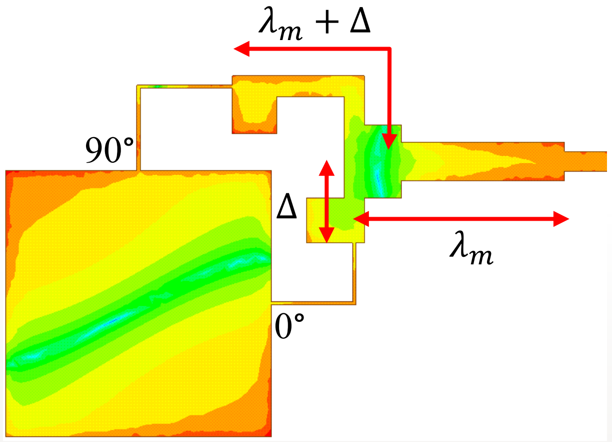


RHCP

Brachline hybrid fed

Have four transmission line connect in square, this method produce equal outputs 90° out the phase at center frequency. The two inputs produce pattern with opposite senses of circular

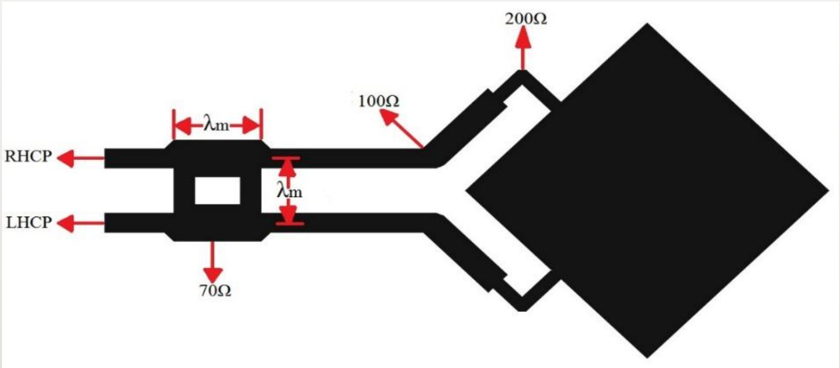
polarization.



RHCP

Corner Truncate

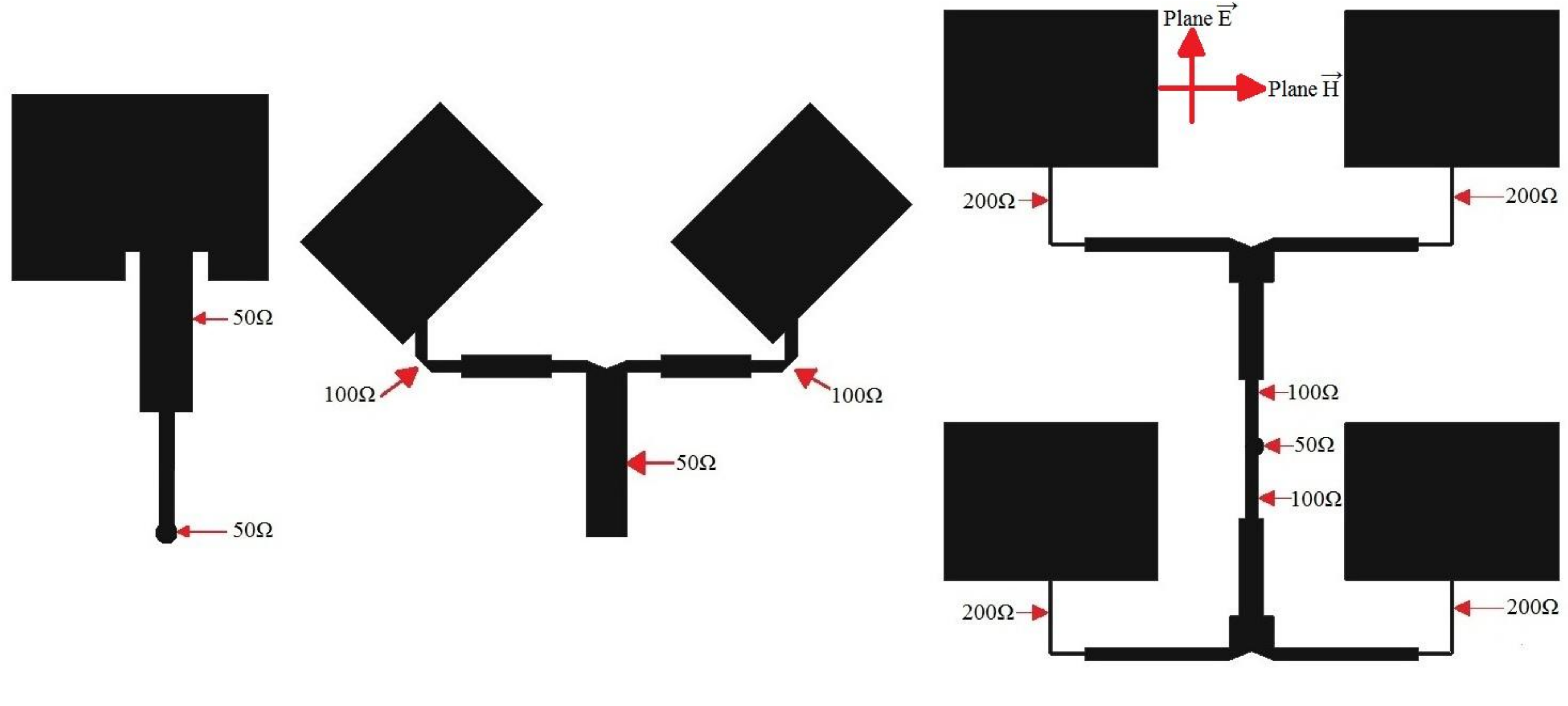
Consists of making cuts in the opposite corners of a patch to get circular polarization



Cross-fed

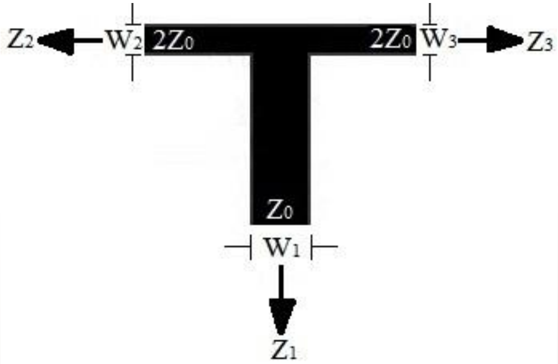
The signal inside in two edges, a transformer a quarter-wave provide the extra 90° phase shift to get circular polarization. Shifting the impedance from one input through a quarter-wavelength line before adding the two in shunt cancel some reflection from the second line and increases the impedance bandwidth

DIVIDER OF IMPEDANCE



Is important to know how many is the impedance that will inside in the patch and this depend of the number of patch in the array.

MICROSTRIP LINES, DISCONTINUITIES AND MATCHING IMPEDANCES

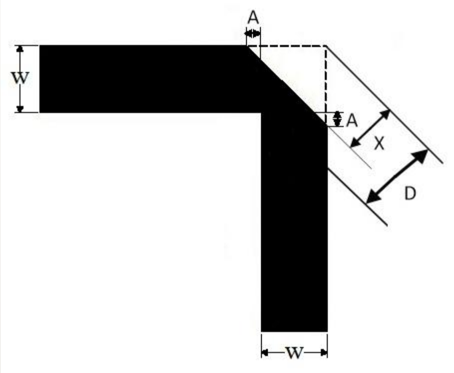


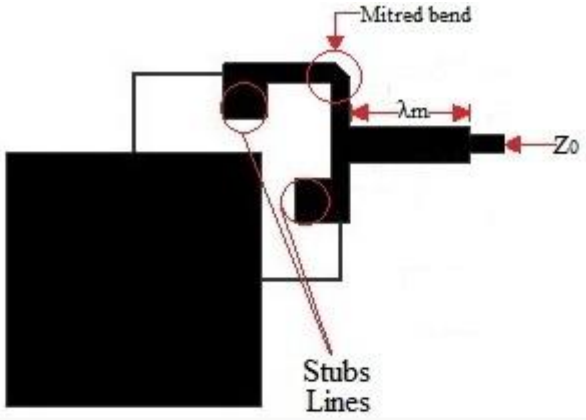
T-junction

Generally the T Junction is used as a power divider when is designed array with microstrip antenna to change of impedance (different width of the microstrip line) and to divide the feed line for two patch. The most common the Wilkinson Power divider where the outside port 2 and 3 have double impedance than inside port 1, to get the maximum potency transferred the outside potency is the half in each port.

Bends

The Bends are generally used when there is a change the direction of the transmission line to avoid capacitances and inductances in the corners due there is a change of impedance when the microstrip line changing. The solution is make a cut in angles in the corners as the angles of Miter.





Quarter-wave Transformer and stub lines

This quarter-wave transformer (λ_m) is the easiest and consisting of the wavelength in the substrate divided by 4. This technique allow to match input impedance (generator) for a real outside impedance (charge). The stubs lines are place in parallel with the microstrip line and the antenna to get matching impedance

Consists of making cuts in the opposite corners of a patch to get circular polarization

ANTENNA SPECIFICATIONS

Carrier frequency	C-band (5.8 GHz)
Incident Power	>=500 mW
Bandwidth	>500 MHz (8,6%)
Polarization	Circular Polarization
Geometry	Planar
Power	500 mW
Gain	>3.0 dB
Directivity	> 3.0 dB
Input adaptation (S_{11})	< -30 dB for 5.8 GHz
VSWR	< = 0,10 dB (1,01:1)
Input Impedance	50 Ω
Axial Ratio	< 3 dB
Half Power beam width (HPBW)	> 50.0°
Accepted Power	450,0 mW
Radiated Power	450,0 mW
Maximum Radiation Intensity	400,0 mW/sr
Radiation Efficiency	> 0,9
Front to Back Ratio	> 300,0

Critical requirements for CubeSat are:

- Gain
- Bandwidth
- Circular Polarization

RT/DUROID® SUBSTRATE

OUTGASSING RESISTENCE OF RT/DUROID® SUBSTRATE COMPARISON				
	RT/duroid® 5870	RT/duroid® 5880	RT/duroid® 6010	RT/duroid® 6002
Composition	PTFE glass-microfiber	FE glass-microfiber	FE glass-microfiber ceramic filler	FE glass-microfiber ceramic filler
Dielectric Constant	2.33	2.2	10.2	2.94
Loss Tangent	0.0012	0.0009	0.0023	0.0012
Total Masa loss (%TML)	0.05	0.03	0.03	0.02
Collected Volatile Consensable Materials (%CVCM)	0	0	0	0.01
Water Vapor Recovered (%WVR)	0.04	0.02	0.02	0.01
TC∈r & CTE OF RT/DUROID® SUBSTRATE COMPARISON				
Stable Dielectric Constant Versus Temperature (TC∈r), ppm/°C -50 to 150°C	-115	-125	-425	+12
Coefficient of Thermal Expansión (CTE (Z)), ppm/°C -0 to 100°C	173	237	24	24

RT/DUROID® 6002 SUBSTRATE

Features & Benefits

- Low Loss
- Reliable multi-layer board constructions
- Reliable Surface Mounted Assemblies
- Sensitive to Temperature Change
- Low outgassing
- Space Applications

CHARACTERISTICS OF RT/DUROID® 6002 SUBSTRATE

Substrate Characteristics		Value	Unit
Dielectric Constant		2.94	-
Dissipation Factor (tan α)		0.0012	-
Thickness	Substrate	1.524	mm
	Copper	0.035	mm
	Ground	0.035	mm
Dimensions		74 x 74	mm

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TIPES OF RT/DUROID® 6002 SUBSTRATE

STANDARD THICKNESS	STANDARD PANEL SIZE	STANDARD COPPER CLADDING
0.005" (0.127 mm)	18" X 12" (457 X 305 mm)	¼ oz. (8.5 µm)
0.010" (0.254 mm)	18" X 24" (457 X 610 mm)	½ oz. (17 µm)
0.020" (0.508 mm)		1 oz. (35 µm)
0.030" (0.762 mm)		2 oz. (70 µm)
0.060" (1.524 mm)		
0.120" (3.048 mm)		
0.060" (1.524 mm)	PROPOSED	1 oz. (35 µm)

PROPOSAL ANTENNA DESIGN

- RT/DUROID® 6002 substrate (e=4.4, tanδ=0.02)
- Thickness: 1.524mm
- Copper cladding: 1/4oz. (8.5 μm), 1/2oz. (17 μm), 1oz. (35 μm), 2oz. (70 μm)
- Size of substrate: 1.43 λ_0 x 1.43 λ_0 at 5.8GHz
- Size each antenna: 0.27 λ_0 x 0.27 λ_0 at 5.8GHz
- Software to design: HFSS

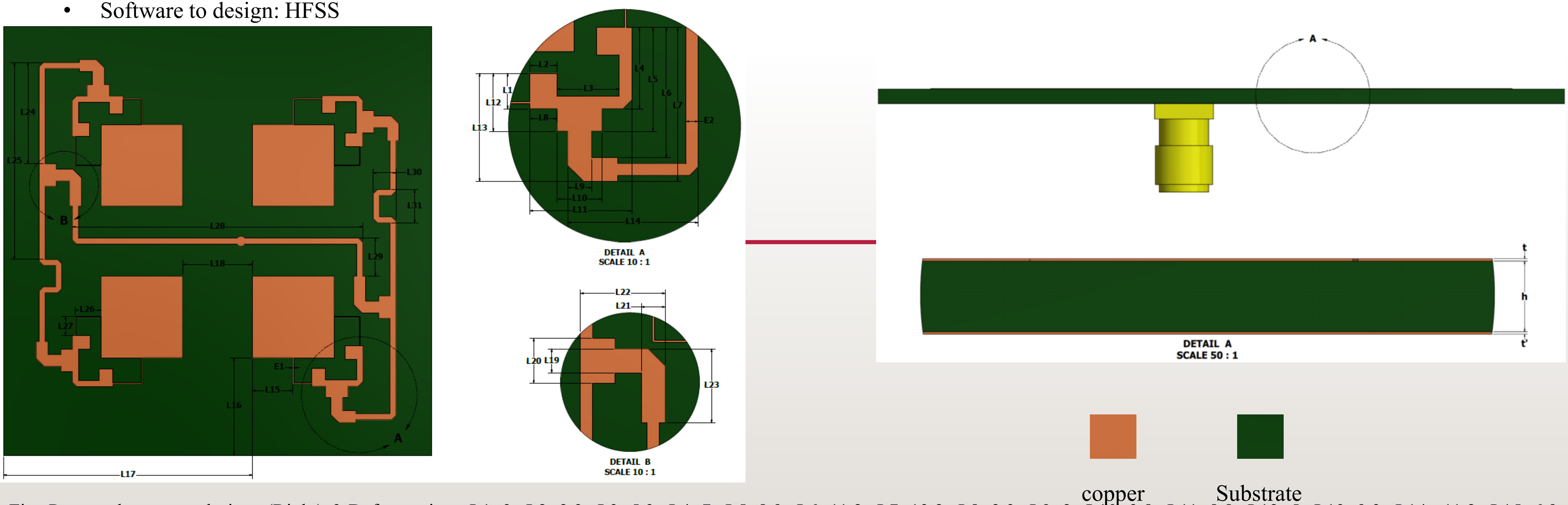


Fig. Proposed antenna design. (Right) 3-D front view, L1=3, L2=2.3, L3=5.3, L4=7, L5=8.9, L6=11.2, L7=13.2, L8=2.3, L9=2, L10=3.8, L11=8.8, L12=5, L13=9.3, L14,=11.2, L15=6.9, L16=16.8, L17=43, L18=12, L19=2, L20=3.8, L21=2, L22=7.3, L23=6.4, L24=17.5, L25=33.9, L26=4.4, L27=3.3, L28=50.1, L29=6.5, L30=3.9, L31=5.7. (Left) Schematic lateral view, t=0.0035, h=0.1524, t`=0.0035. (All dimension are in mm)

ELECTRICAL FIELD, MUTUAL COUPLING & RADIATION PATTERN

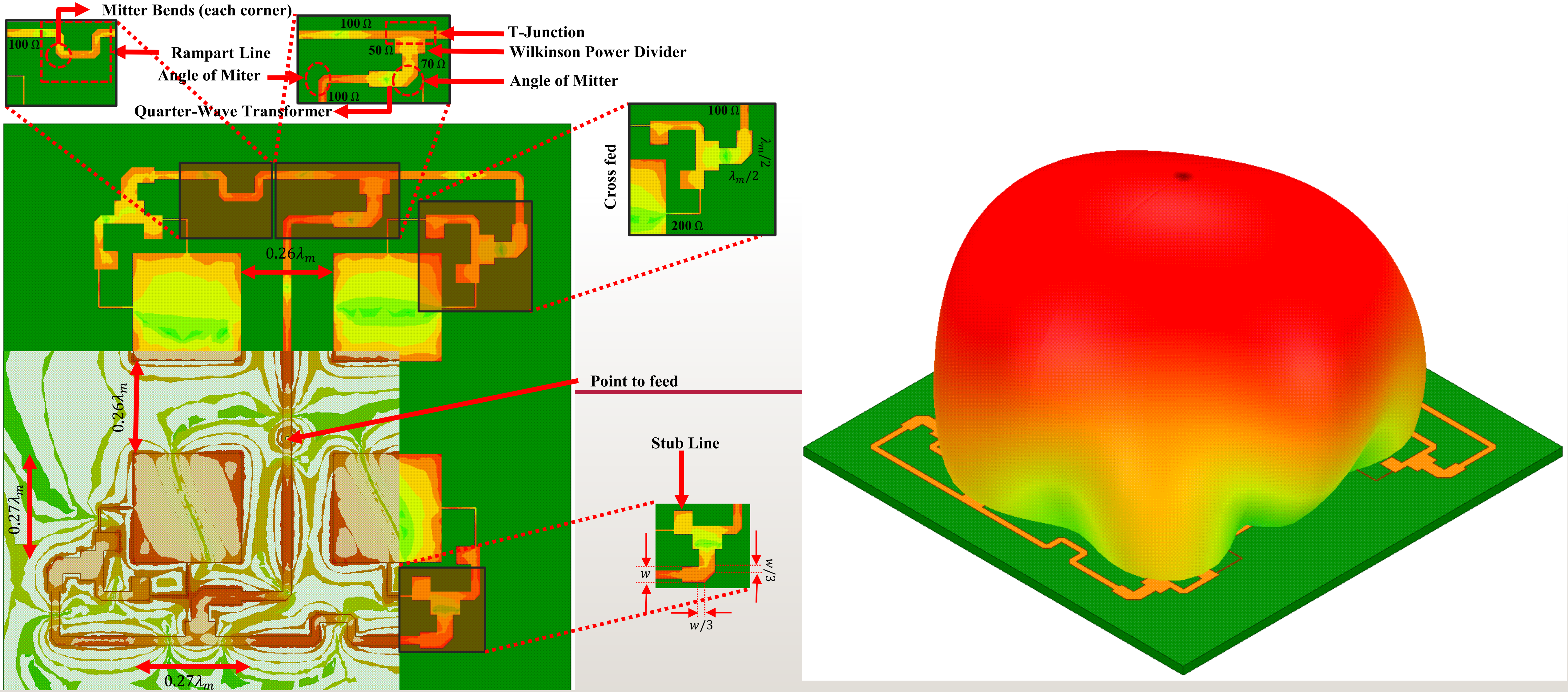
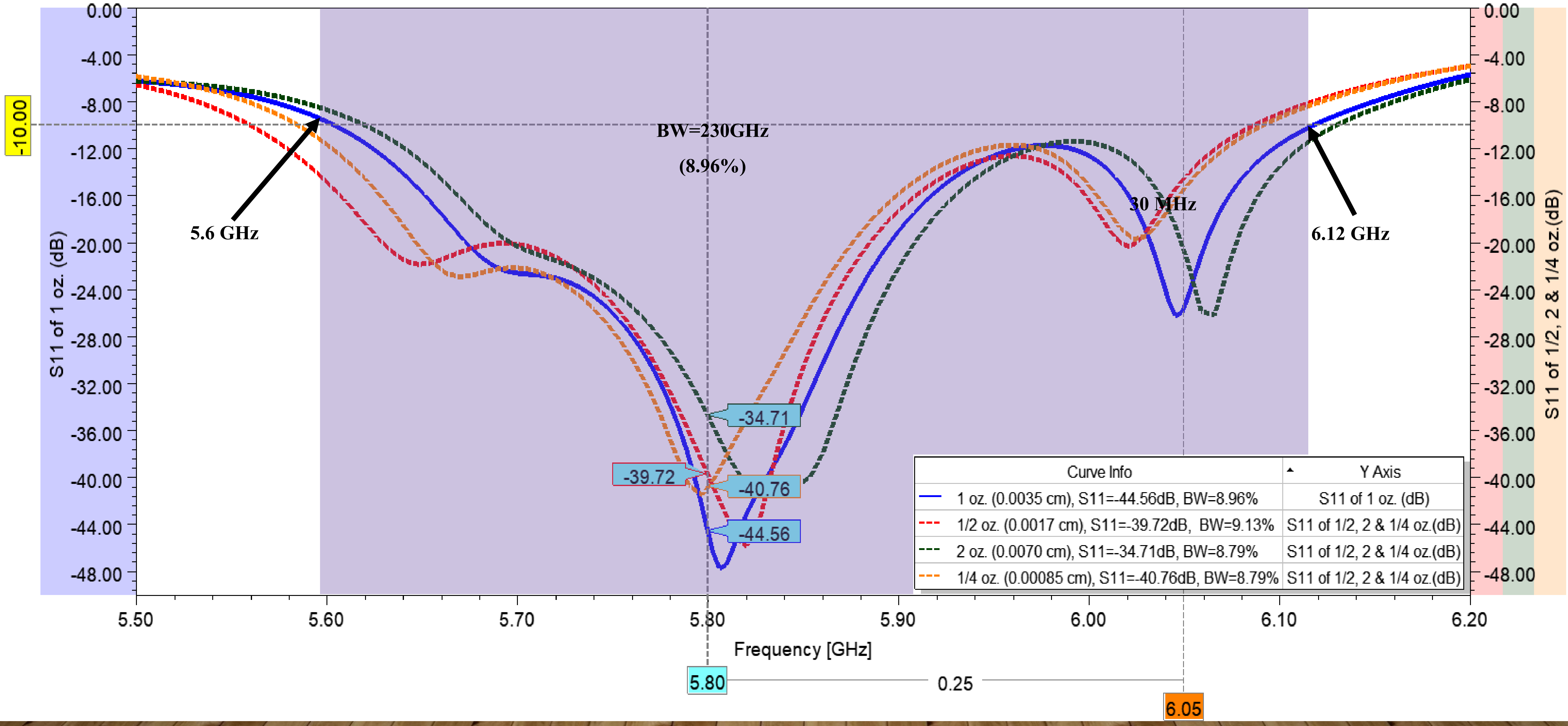
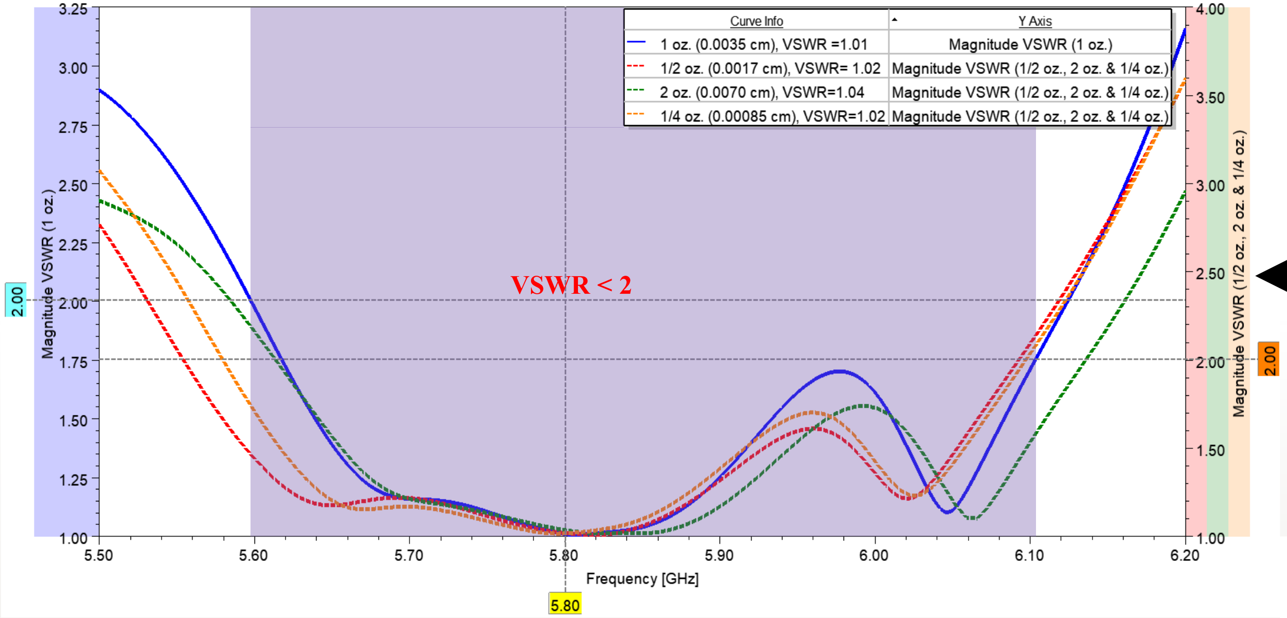


Fig. (Right) Electrical field with mutual coupling in 2D (Left) Radiation partner in 3D

COMPARISON OF S11 BETWEEN DIFERENT COPPER CLADDING

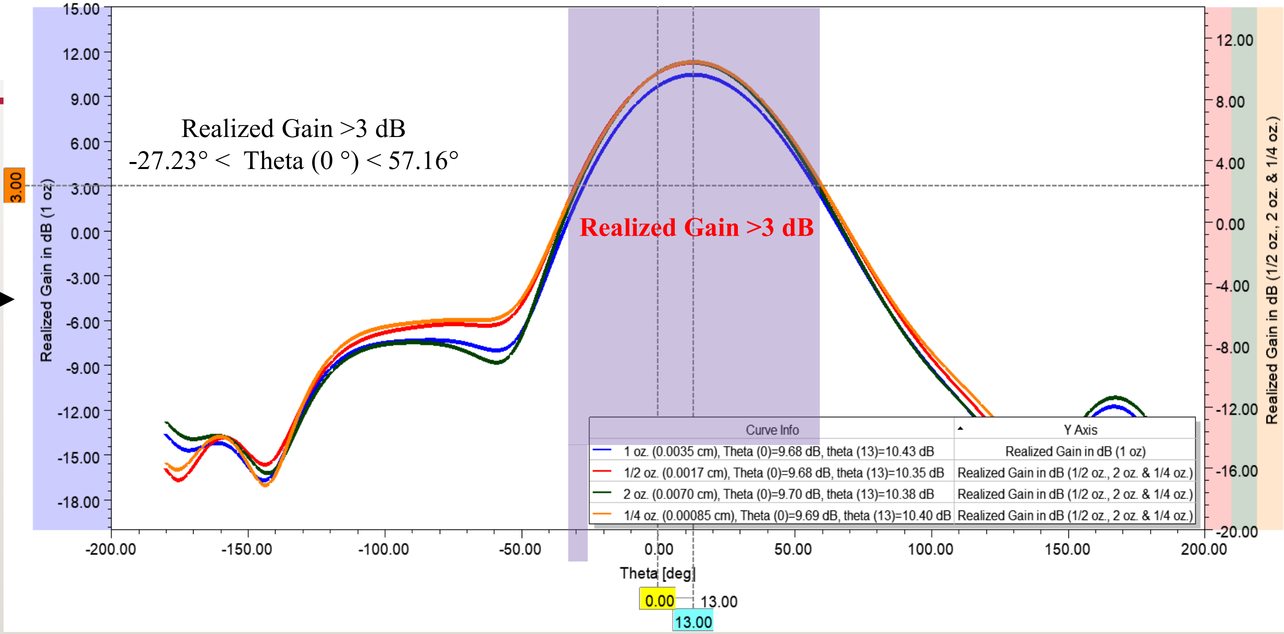


VSWR & REALIZED GAIN BETWEEN DIFFERENT COPPER CLADDING

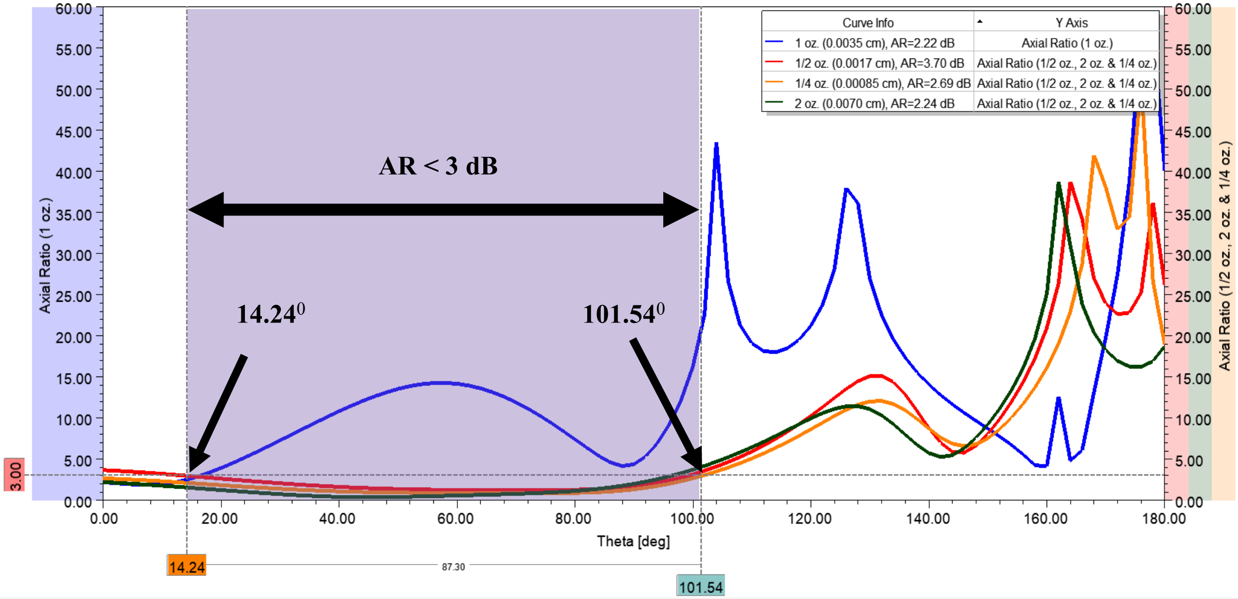


In VSWR is shown for frequency of 5.8GHz was 0.10dB and is seen that in 6.05GHz is 1.11dB that is less that 2dB and this ratio is considered in the graphic of return loss. This result is an index that show the matching impedance is 50Ω.

A disadvantage in microstrip antennas is that have very poor gain, but to improve it and to can use in space applications are used in array, the realized gain was 10.43dB in $\theta=13^0$ and in $\theta=0^0$ the gain in 9.68dB with 0.75dB of difference.

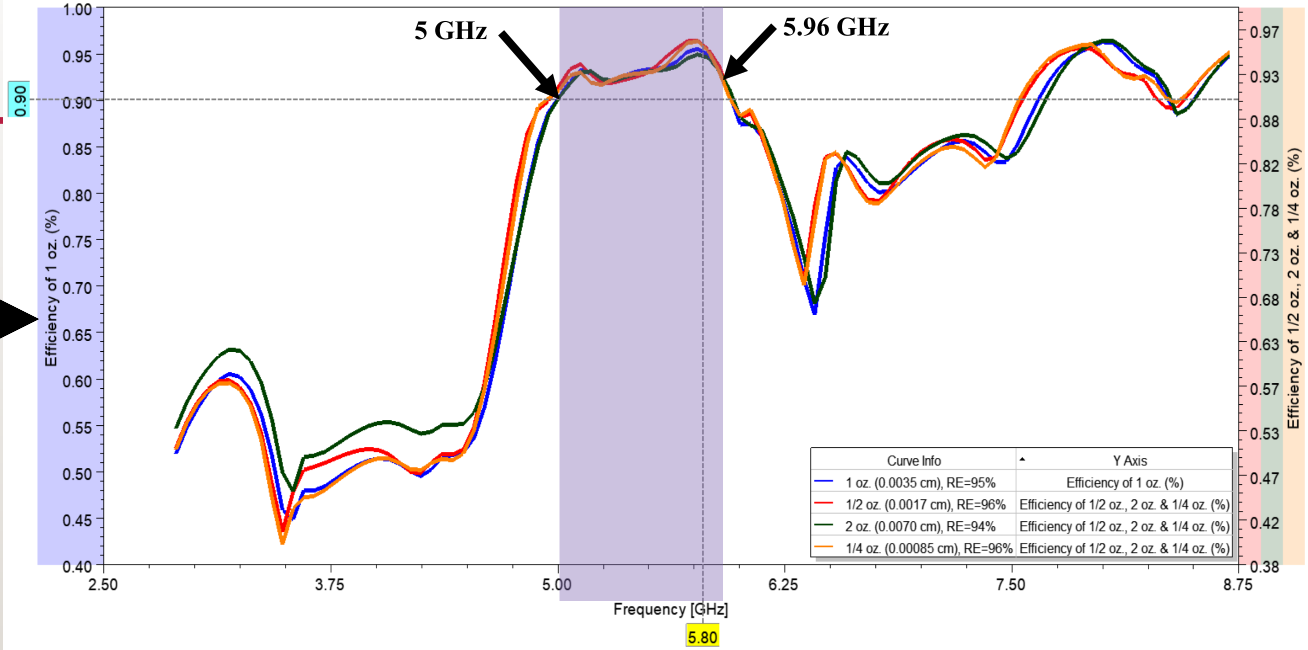


AXIAL RATIO & RADIATION EFFICIENCE BETWEEN DIFFERENT COPPER CLADDING



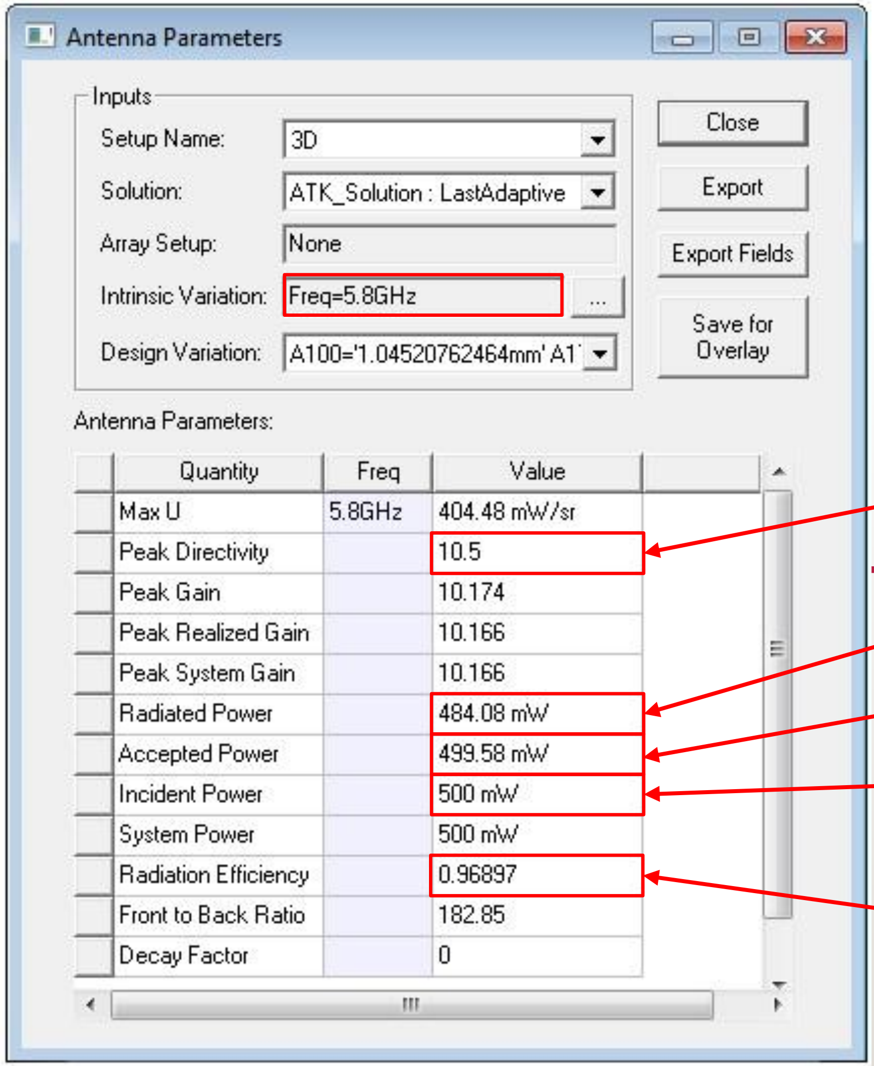
The axial ratio was 2.22dB for $\theta = 0^0$ for substrate with copper cladding 0.0035 mm.

Radiation efficiency was higher than 90% with copper cladding 0.0035mm.



ANTENNA PARAMETERS

Analyzes of the different parameter in the microstrip antenna array was made when was assembly in the CubeSat to get similar conditions where will be working. The microstrip antenna array will connected with the transmitter and with the goal to find if it is efficient when transmitting information of the different sensors that will be in the CubeSat is analyzed the relation of the power transmitted with the power received of the transmitter. Efficiency Radiation (η) should be high to get a maximum transmission power.
To know how much the Radiated Power of the microstrip antenna array is necessary find the Incident Power form transmitter, the CubeSat are using transmitters with 500mW and approximately 7.0711 V



Quantity	Freq	Value
Max U	5.8GHz	404.48 mW/sr
Peak Directivity		10.5
Peak Gain		10.174
Peak Realized Gain		10.166
Peak System Gain		10.166
Radiated Power		484.08 mW
Accepted Power		499.58 mW
Incident Power		500 mW
System Power		500 mW
Radiation Efficiency		0.96897
Front to Back Ratio		182.85
Decay Factor		0

$$M_{ax}U = \frac{D_{peak} * R_{power}}{4 * \Pi}$$

$$R_{power} = \eta * A_{power}$$

$$A_{power} = I_{power} * (1 - |\Gamma|^2)$$

$$I_{power} = \frac{1}{8} * \frac{{V_{T_x}}^2}{R(\Omega)}$$

The total power is the contribution of the 4 antennas

$$\eta = \frac{G_{peak}}{D_{peak}} = \frac{R_{power}}{A_{power}}$$

ELECTRICTRICAL FIELD AND RADIATION PARTNER AT THE CUBESAT

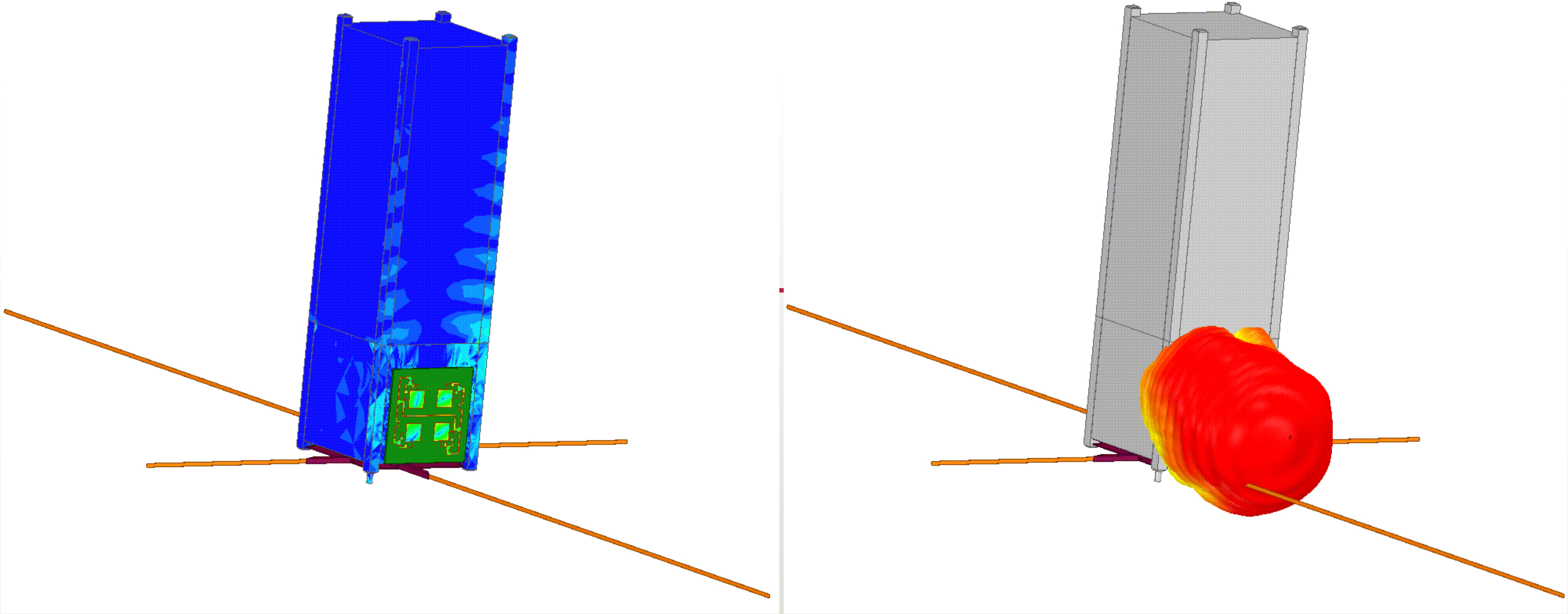
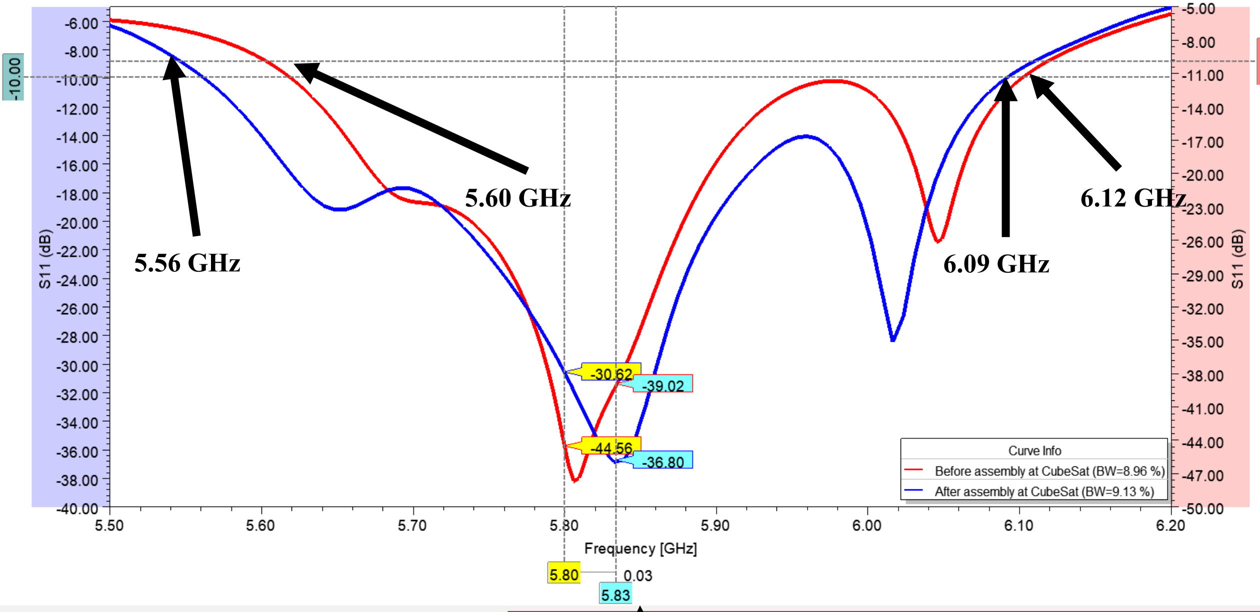
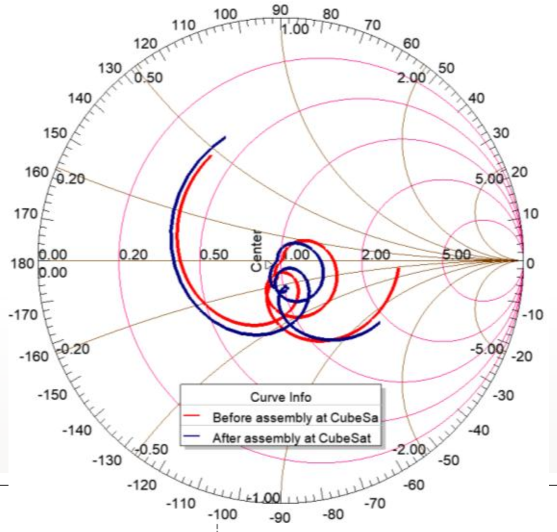
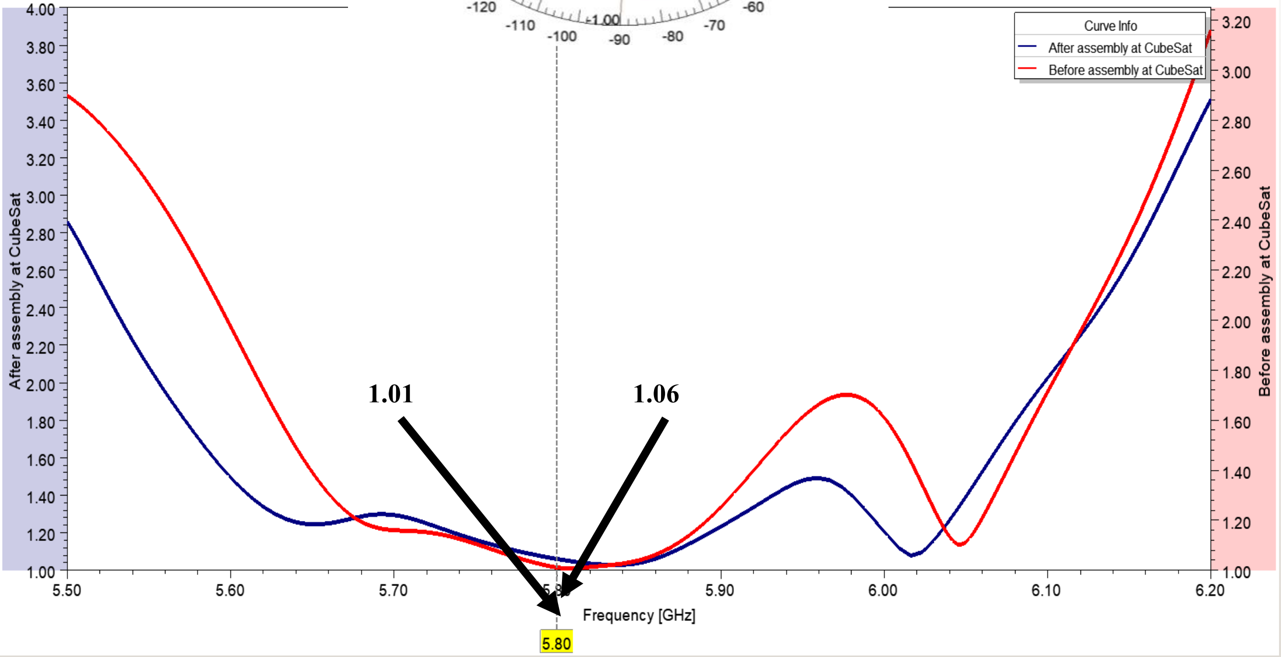


Fig. (Right) Simulated surface current distribution on CubeSat (Left) Radiation partner in 3D after assembly

COMPARISON BETWEEN S11, SMITH CHART & VSWR BEFORE AND AFTER ASSEMBLY

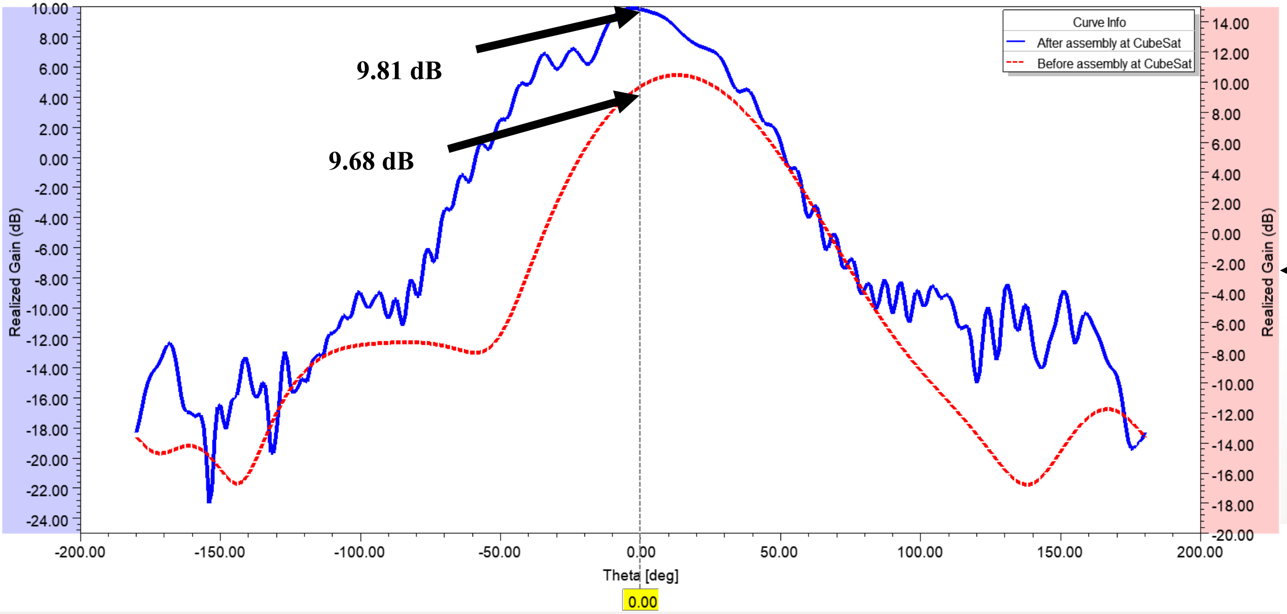






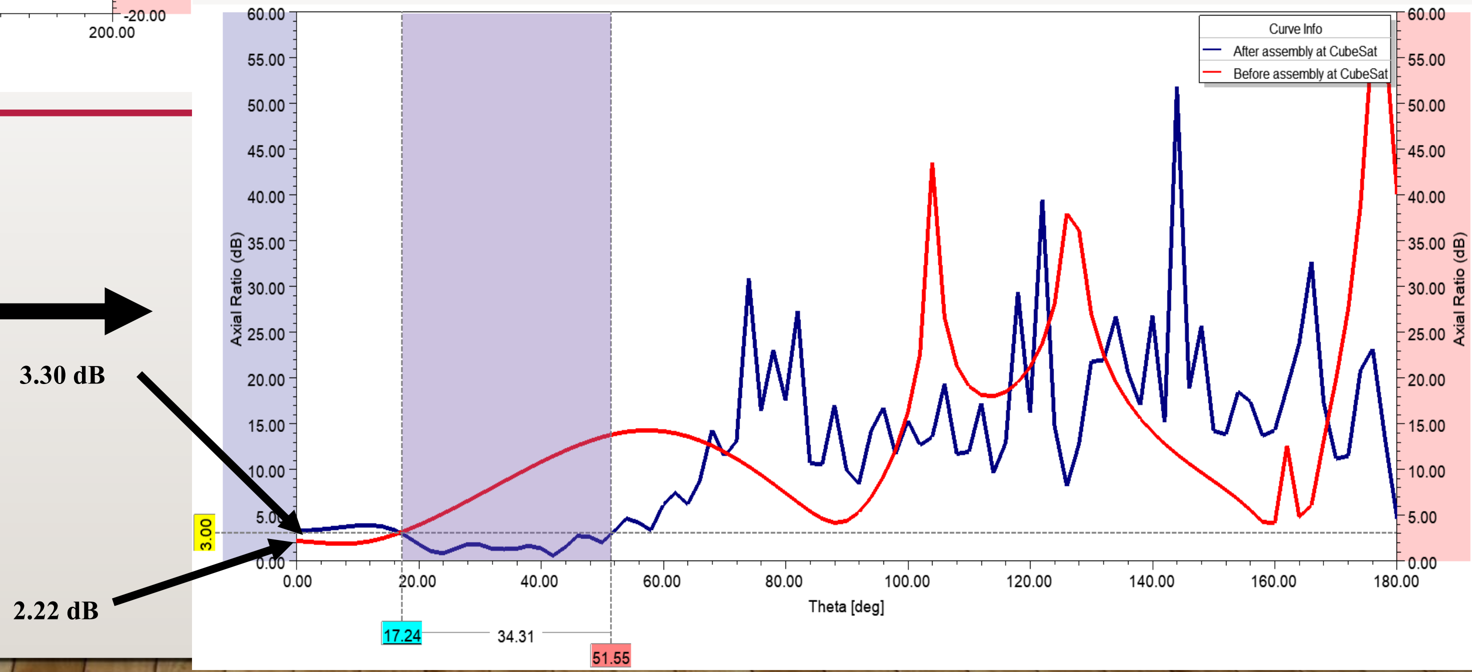
Return loss after of the assembly in the CubeSat is -30.52dB. The different before assembly in the CubeSat is -13.94dB below that when is assembly. The BW is improved when is assembly until 9.1% with 530MHz.

COMPARISON BETWEEN REALIZED GAIN & AXIAL RATIO BEFORE AND AFTER ASSEMBLY



The realized gain is less and is 9.81dB but is an excellent value to use in CubeSat.

Circular polarization present an increase and is found, AR< 3dB from 17.24^0 until 51.55^0 but in $\theta=0^0$ was 3.30dB.



CONCLUSION

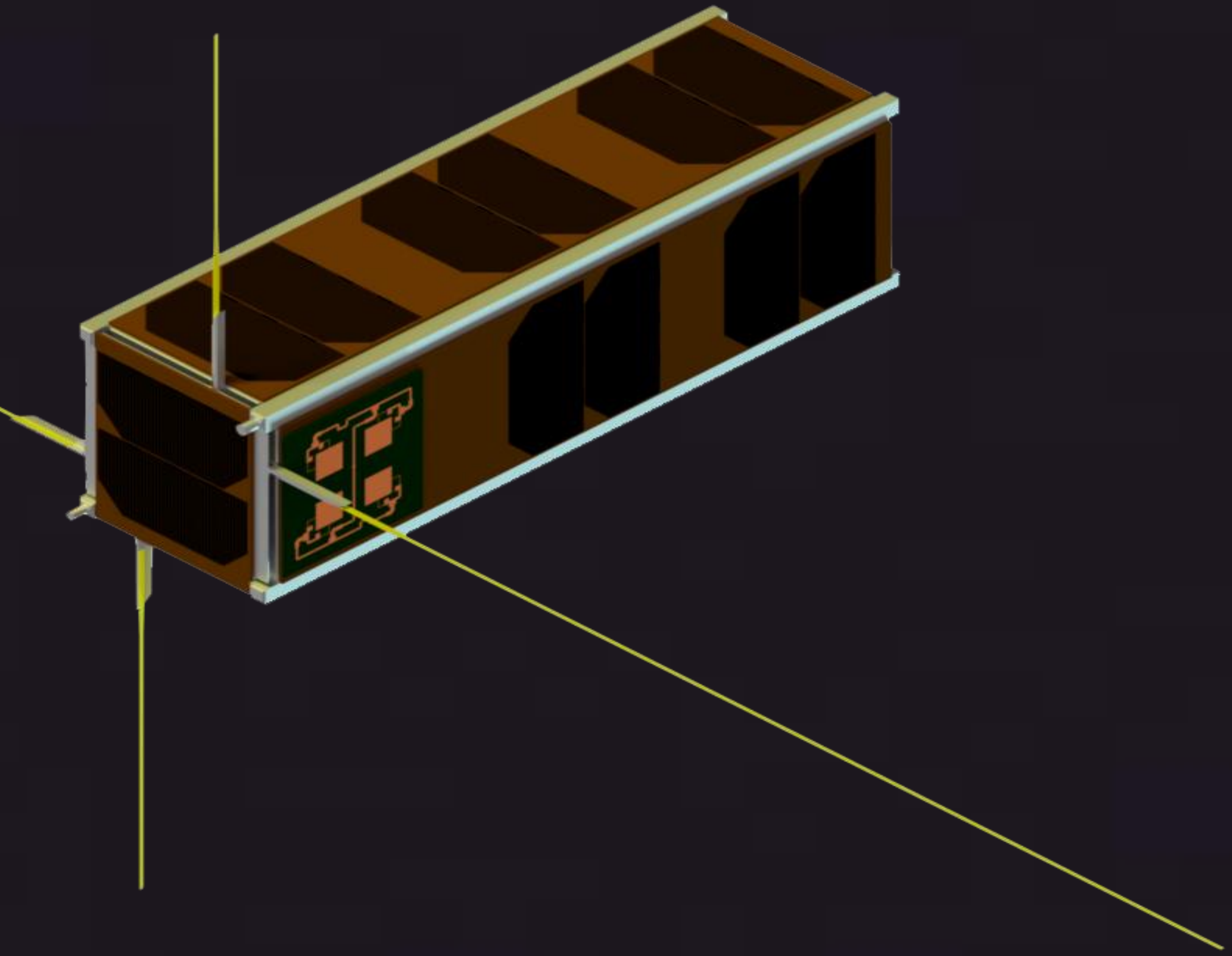
1. The last decade has seem an emerging research in the field of circular polarized antenna to space applications as well as in CubeSat.

2. The potential research in microstrip antenna with circular polarized in with ultrawide band is very challenging.

3. Using different methods and techniques to research antennas for space application will allow improvement the transmission data of a lot of sensors.

4. From antenna development with cross feed have gained a lot importance because of their ability to improve the bandwidth

Thank you for listening !



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