Mechanical component

Context

To carry out its mission, CubeSat has to send data of telemetry to a ground station.

For this, our system uses a module of telecommunication which include an antenna to emit data up to a ground station.

This module includes a transceiver and an antenna.

The transceiver handles data to emit them via the antenna.

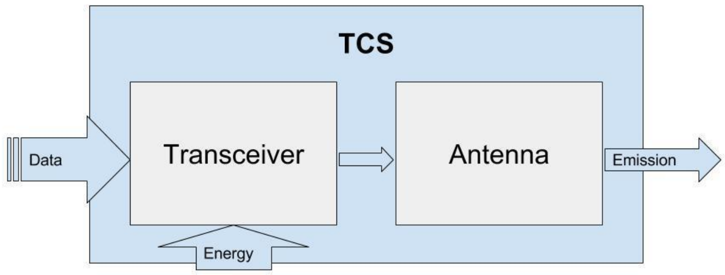


Figure 3: Simplified scheme of the TCS

The on-board computer (OBC) of the satellite provides data to be sent to the TCS module which emit these data. The antenna is the last subsystem of this module.

Main function

The role of the antenna of CubeSat is to create the electromagnetic waves which contain the necessary information for the realization of the spatial mission to be able to receive them and interpret them on the ground.

The system converts the existing electric signal containing the information in electromagnetic signal in the space.

Technical constraints

The characteristics of efficiency, the antenna gain and the antenna radiation pattern influence directly the performances of the quality and the range of the system.

The output power increases with the frequency and gain of the antenna, so
our band for downlink communications is 435-438 MHz.
The average power consumption of our module must be less than 1.5W, and the mass of the CubeSat must not exceed 1,33 kg.

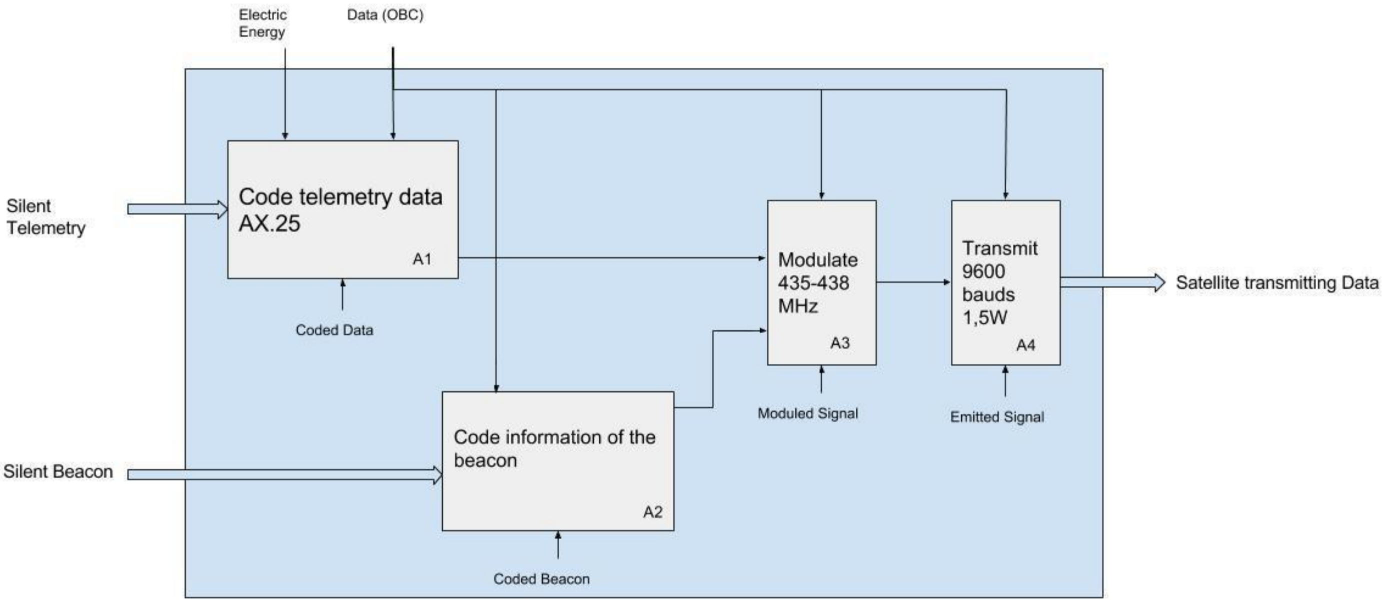
With the aim of the specifications system, the antenna must be compatible with the following criteria:

- Transmission rate: 1200 to 9600 bauds
- Broadcast max power: 1,5W
- Frequency band: 435 to 438 MHz
- Antenna gain max: 0 to2 dB
- Dipole length: λ/4 minimum, λ/2 required
- Interface: I^2C
- Envelope stowed: 98 mm x 98 mm x 7 mm

Figure 4: Advance scheme of the TCS module

With the aim of the characteristics of the environment of use, the antenna must be compatible with the following criteria:

- Thermal constraint: -150°C to +150°C
- Radiation constraint: resisting UV radiation, X, protons, and plasma in LEO
- The friction on the external surfaces including the antenna shall not impact its functioning
- The erosion due to the Oxygen (200-100km) must be managed
- The luminescence due to the Oxygen (200-100km) must be managed



- Launch vibrations

Existing antennas

Below the categories of existing antennas:

- Dipole
- Monopole
- Turnstile
- Helios (too voluminous for 1U nanosatellite)
- Micro strip patch

Models	Gain	Effective isotropic radiated power	Bandwidth
Dipole	0 dB	2W	>10MHz
Monopole	0 dB	2W	>10MHz
Turnstile	1.5 dB to -1dB	2W	>10MHz
Micro strip patch	<10 dB	4W	2300-2500 MHz

Figure 5: Summary of type of antennas for CubeSar

Selection of compatible antennas

Modulation scheme data rate: for downlink applications on UHF, downlink speeds between 1200 and 9600 bauds are considered. High order modulation schemes offer better spectrum efficiency but increase the complexity of the link and they can increase the risk of failure. QPSK (Quadrature phase-shift keying) modulation begins to be used commonly in Sband but more complex schemes (like 8PSK or 16APSK), which are common in satellite broadcasting, are still not used for nano-satellites.

Antenna deployment: for UHF antennas the main development trend has not been primarily in the improvement in the overall performances (limited by physical size and spacecraft requirements for omni directionality), but rather in the reduction of the volume required to include them in the cube. As of now these antenna systems are now available as commercial off-the-shelf systems with proven performance from different suppliers.

Bands: for the relatively newer and higher frequency bands the trend is to design patch antennas first with simpler linear polarization, the main reason for the selection of this antenna is the limited size according to a good gain. L-band and S-band patches unfortunately require a big portion of a CubeSat panel to be fitted, taking area from solar panels. Sometimes small monopoles have been used due to the easiness of development and production. Bigger antennas as of now seem still infeasible due to the available size. Antenna arrays could also be possible but their usage is limited to higher frequencies due to the available size of the panels. Phased arrays can open a wide variety of new possibilities by allowing for example electrical beam steering. Highly directive antennas are currently rarely used in CubeSats mainly because the pointing accuracy is most of the times quite limited or no active attitude control is available. This forces the antennas to be generally omni-directional, such as monopoles or dipoles.

Choice: for the choice of the antenna, two companies designing parts for CubeSats could propose interesting solutions for our project: ISIS and Clyde Space, both proposing systems of antennas.

Models	Required power	Data rate	weight
ISIS turnstile	2W	1200 - 9600 bauds	<100g
ISIS dipole	2W	1200 - 9600 bauds	<100g
ISIS monopole	2W	1200 - 9600 bauds	<100g
Clyde Space CMC UHF	4 - 10W	1200 - 9600 bauds	<90g

Figure 6: Main antennas proposed by space companies

Our choice is towards a solution similar to the ISIS dipole antenna because characteristics match with system and environmental specifications:

- low gain: 0bB in UHF
- <2W
- 1200 - 9600 bauds
- <100g
- almost omnidirectional
- Dipole length: λ/2

Simulation

We made a simulation using EZNEC, an antenna modeling program. The objective of the following part is to show that we can simulate the oscillatory behavior in relation to the geometry of the antenna.

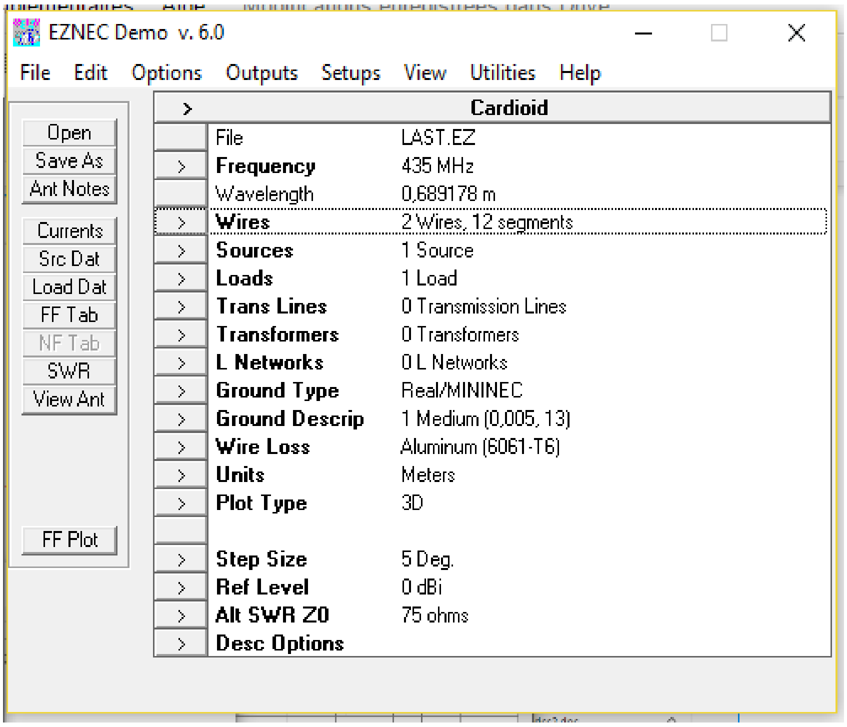


Figure 7: Parameters of our simulated antenna

First we modeled wires of the antenna. We created two Wires. The common center point is at 0, 0, 600km. They share that coordinate. By clicking the View Ant button on the main EZNEC window, we can get a 3D view of the antenna.

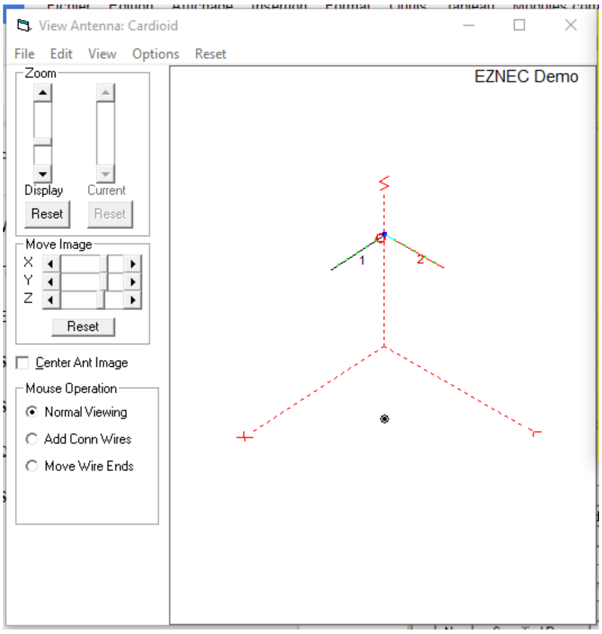
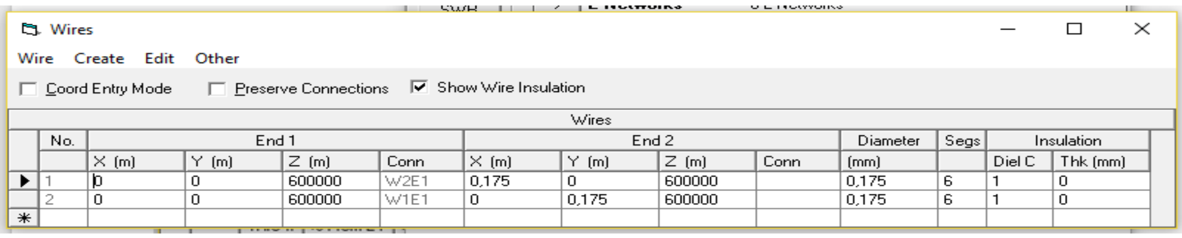
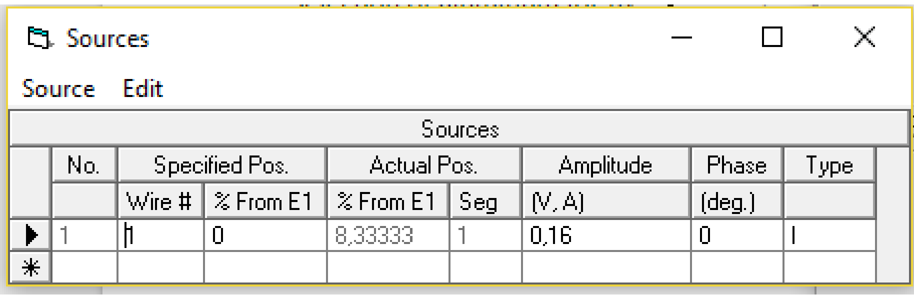


Figure 8: Two wires of the simulated antenna



Wires												
No.	End 1				End 2				Diameter	Segs	Insulation	
	X (m)	Y (m)	Z (m)	Conn	X (m)	Y (m)	Z (m)	Conn	(mm)		Diel C	Thk (mm)
1	0	0	600000	W2E1	0,175	0	600000		0,175	6	1	0
2	0	0	600000	W1E1	0	0,175	600000		0,175	6	1	0

Now we can configure the source, the Source is placed at the bottom of the Wire, in segment 1 :



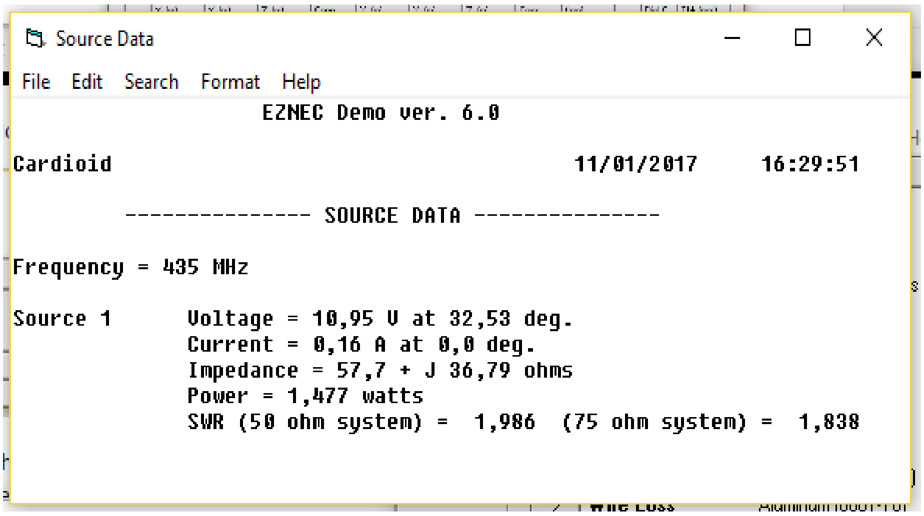
Sources

Source Edit

Sources							
No.	Specified Pos.		Actual Pos.		Amplitude	Phase	Type
	Wire #	% From E1	% From E1	Seg	(V, A)	(deg.)	
1	1	0	8,33333	1	0,16	0	I

The important part of this configuration is the selection of the Real/MININEC Ground Type, and the selection of aluminum for the Wire material.

In the Source Data windows, we can generate the Source data report, which is:

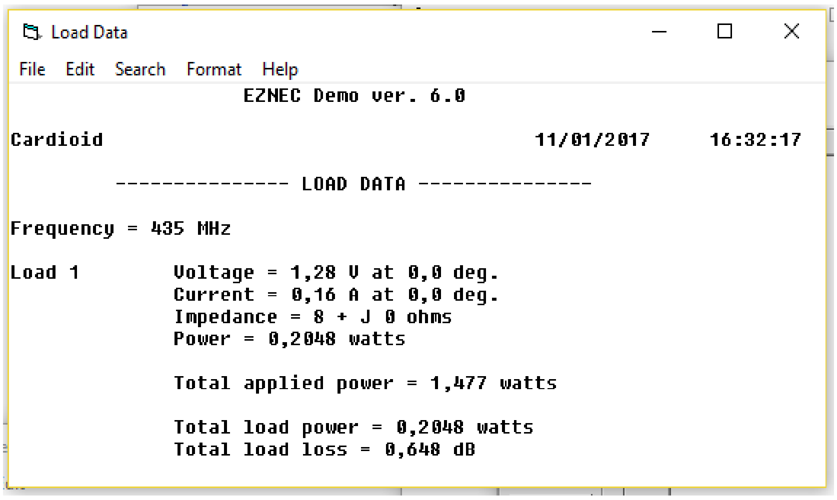


Source Data

File Edit Search Format Help

```
                    EZNEC Demo ver. 6.0

Cardioid                                 11/01/2017      16:29:51

          --------------- SOURCE DATA ---------------

Frequency = 435 MHz

Source 1      Voltage = 10,95 V at 32,53 deg.
              Current = 0,16 A at 0,0 deg.
              Impedance = 57,7 + J 36,79 ohms
              Power = 1,477 watts
              SWR (50 ohm system) =  1,986  (75 ohm system) =  1,838
```

We can display the Load Data, which is a proxy for the ground loss. The report is:



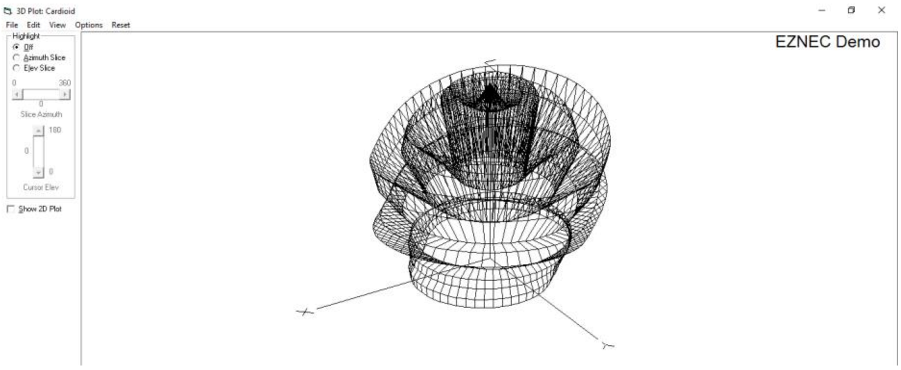
Load Data

File Edit Search Format Help

```
                    EZNEC Demo ver. 6.0

Cardioid                                 11/01/2017      16:32:17

          --------------- LOAD DATA ---------------

Frequency = 435 MHz

Load 1        Voltage = 1,28 V at 0,0 deg.
              Current = 0,16 A at 0,0 deg.
              Impedance = 8 + J 0 ohms
              Power = 0,2048 watts

              Total applied power = 1,477 watts

              Total load power = 0,2048 watts
              Total load loss = 0,648 dB
```

Of the 1,477 watts supplied to the antenna, 0,2048 watts are dissipated in the ground loss. The impact of that loss on the gain is 0,648 dB. In other words, if the ground loss was 0 Ohms, we would have 0,648 dB of added gain.

Now let display the 3D simulation of this system configuration:



Sources

https://www.isispace.nl/product-category/satellite-products/antenna-systems/

http://www.gomspace.com/index.php?p=products-ant430

http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2368&context=etd