Phase A

RF Antenna

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FOREWORD

I thank the LEMA (especially my advisor J-F Zürcher) and all the SwissCube Team for their help and support.

INTRODUCTION

This semester's project will examine a catalog of propositions for the selection of the antenna system onboard SwissCube (the Swiss Student Satellite). The SwissCube-project's aim is to build a Cubesat.
In the introduction it will be given a description of the Cubesat concept and SwissCube mission's objectives and defined some terms related to antenna's measures. Chapter 2 will define the semester's objectives. Chapter 4 will list assumptions and tools used to do the design's analyses which will be exposed in chapter 5. In chapter 6 some analysis recommendations will be described. Finally the conclusion and future work are in chapter 7.

The Cubesat concept

The Cubesat program started in 1999. It was developed by Professor Robert Twiggs at Stanford University's Space System Development Laboratory in collaboration with California Polytechnic State University.

The goal was to give students hands on experience in satellite designing. One of the advantages with this project is that it is low-cost and quick to launch. The Cubesat is a picosatellite, meaning it has to weigh 1000 grams or less. It is also limited to a cube, which the name implies, and has to have the dimensions of 10 cm x 10 cm x 10 cm to fit into the PPOD, Poly-Picosat Orbital Deployer. Such a standardized vehicle increases the launch opportunities for student satellites.

The SwissCube mission's objectives

The Swiss Cubesat project, SwissCube, is collaboration between students at Swisss Federal Institute of Technology EPFL, Université de Neuchatel, HES Sion, HES Yverdon, HE-ARC. The SwissCube's primary objective is to deliver a fully tested Cubesat to launch site in 2008. Then, the secondary objectives are to launch, close RF link and finally take comprehensive measurements of the NightGlow Phenomena. It implies the necessity to have a functional RF subsystem.

1 REFERENCES

[R1] Antenna system for NCUBE, Diploma Thesis, June 16, 2003, Jan Otterstad

[R2] Official website of the International CubeSat Project : http://cubesat.calpoly.edu/

[R3] Website of Univesity of Tokyo : http://www.space.t.u-tokyo.ac.jp/cubesat/index-e.html

[R4] Website of Aalborg Cubesat : http://www.cubesat.auc.dk/

[R5] Website of Wikipedia : http://en.wikipedia.org

[R6] Traité d'éléctricité pour le radioamateur : http://perso.orange.fr/f6crp/elec/index.htm

[R7] Antenna deployment by Mario Greber

2 PROJECT OBJECTIVE

The goal of this project would be to analyze the antenna pattern of the Cubesat dipole antenna depending on its location on the satellite et depending on the characteristics of the satellite structure and materials used. This project will use already developed simulation tools.

3 TERMS, DEFINITIONS AND ABBREVIATED TERMS

3.1 Abbreviated terms

RF	radio frequency
VHF	very high frequency (from 30 to 300 MHz)
UHF	ultra high frequency (from 300 MHz to 3 GHz)
dB	decibel
dBi	decibels over isotropic
S11	return loss in dB
S21	coupling in dB
λ_0	2057 mm (wavelength of 145.8 MHz)
λ_1	685 mm (wavelength of 437.5 MHz)
Z_L	load impedance
Z_0	line impedance

Balun device designed to convert between balanced and unbalanced electrical signals, such as between coaxial cable and ladder line.

4 DESIGN ASSUMPTIONS AND APPROACH

4.1 Antenna types

An antenna is a conductive element which converts electrical energy into an electromagnetic field (transmit), or converts an electromagnetic field into electrical energy (receive). An important feature is the property of reversibility, the same antenna can be used with the same characteristics as a receive antenna. An antenna is characterised by its center frequency, bandwidth, polarisation, gain, radiation pattern and impedance.

According to the Swisscube's structure, this analysis treats two elementary omni directional antennas the monopole (figure a) used by Ncube (figure 4b) or XV-I (figure 7) and the dipole (figure b) used by XI-V (figure 7) or Hawaiian Cubesat. Indeed the satellite's dimensions and the envisaged frequencies (see 3.5) don't permit to include antenna in solar panels.

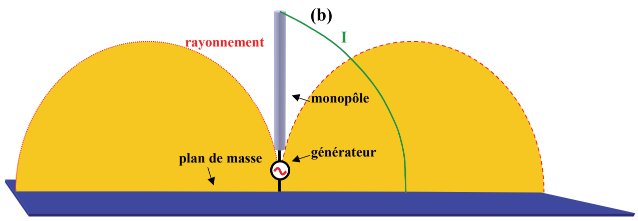


Figure a: monopole antenna

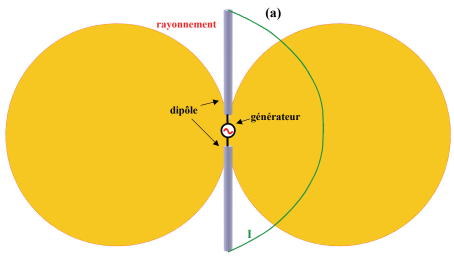


Figure b: dipole antenna

4.2 Radiation patterns

The radiation pattern is a graphical representation of the radiation properties (far-field) of an antenna. In this report, 3D polar radiation plot are used to illustrate the results, the gain will be given in dBi (this is the power in the strongest direction relative to the power that would be transmitted by an isotropic antenna emitting the same total power). For instance, the figure 1 is the 3D polar radiation plot of a dipole antenna (314mm excited at 437,5MHz) in free space oriented along Oy axis, it shows a max gain of 2.65dBi (about 184% of original signal).

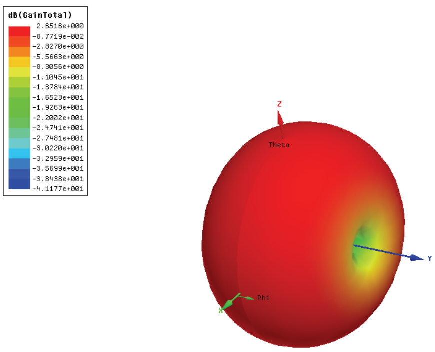


Figure 1: Radiation pattern at 437.5 MHz for dipole antenna

4.3 S-parameters

Radio communication theory, states that the antenna impedance Z_L, has to be matched to the transmission line Z_0. The reason for this is that maximum power transfer between source and load occurs when the system impedances are matched. It also improves the signal-to noise-ratio for the system and reduces amplitude and phase errors.

The match can be described by the reflection coefficient: $(Z_L-Z_0)/(Z_L+Z_0)$

The reflection coefficient varies from -1, for short load, to +1, for open load, and becomes 0 for matched impedance load.

The Return Loss, S11, is a common expression used in antenna measuring. This is basically the same thing as reflection coefficient. If 50 % of the signal is absorbed by the antenna and 50 % is reflected back, we say that the Return Loss is -3dB. A very good antenna might have a value of -10dB, 90 % absorbed and 10 % reflected.

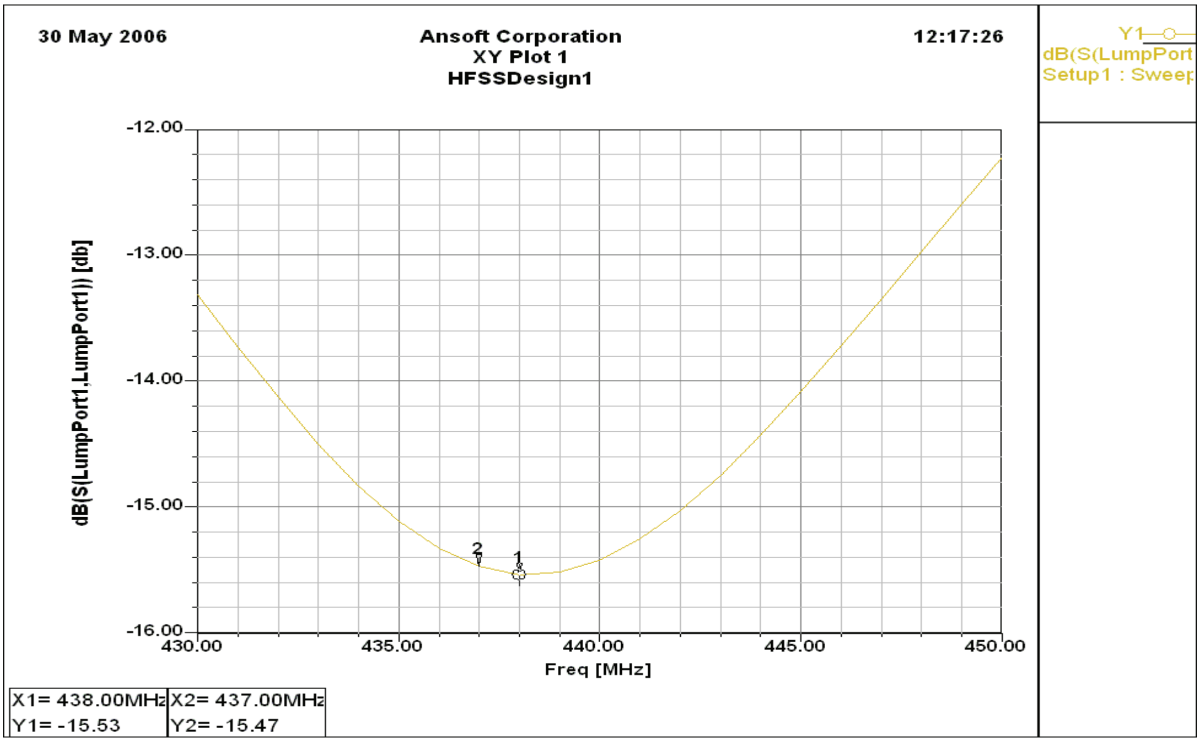


Figure 2: S11 parameter plot for dipole antenna

For instance, the figure 2 shows the s11 parameter in dB according the frequency in MHz for a dipole antenna of 314 mm in free space. At 438MHz, there is a return loss of -15.53 dB, less than 3% of the signal is reflected.

4.4 Frequency and wavelength

Actually, the frequencies were not fixed, but I supposed that the uplink (from ground station to satellite) is about 145.8 MHz (VHF band) and the downlink (from satellite to ground station) is around 437.5 MHz (UHF band). The wavelengths are λ_0 = 205.7 cm for 145.8 MHz and λ_1 = 68.5 cm for 437.5 MHz.

Theoretically the dimension of a quarter-wavelength monopole antenna at these frequencies is 17.1 cm for UHF and 51.4 cm for VHF. For half-wavelength dipole antenna, the theoretical lengths are 34.2 cm for UHF and 102.8 cm for VHF case.
In this report, the antenna for 145.8 MHz will be called the VHF antenna and the other UHF antenna for 437.5 MHz.

4.5 HFSS simulations

The used software to analyze the radiation patterns, return loss and other parameters of antenna was Ansoft HFSS. In HFSS, the SwissCube was designed as a full metallic cube of 100mm * 100mm * 100mm made of aluminum because at this moment we don't know the exact structure of satellite and it simplifies the problem. Around the satellite, it was supposed to be vacuum. For monopole antenna we consider a coaxial cable with waveport excitation of Z_0=50Ohms at entry. The radius of the central conductor (figure 3a) is 1.3mm and the dielectric (vacuum) is 3mm . For dipole antenna we use lumped port of Z_0=50Ohms as a symmetric source of excitation. The length of lumped port is 5mm (figure 3b). The distance between satellite and antenna is 3 mm, the antenna's width is 3 mm and thickness is negligible.

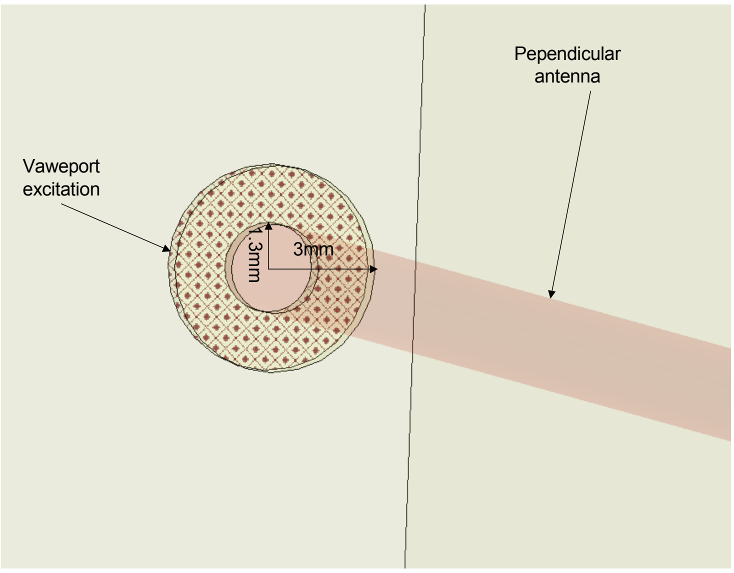


Figure 3a : schema of the perpendicular monopole antenna

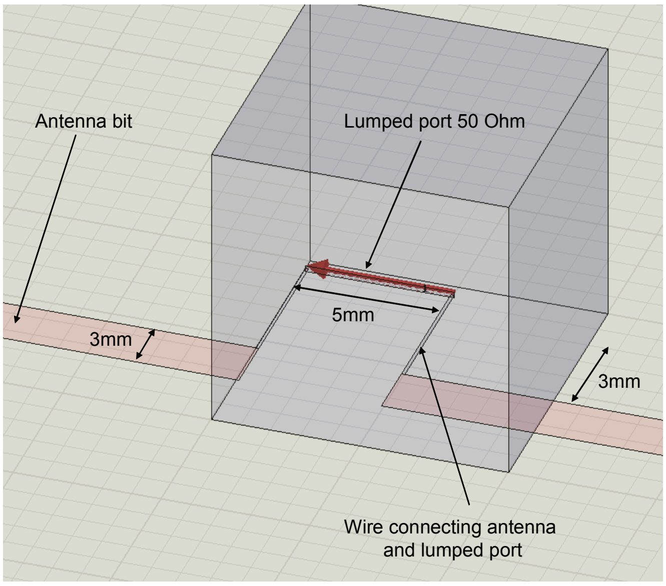


Figure 3b : schema of the dipole antenna

5 DETAILED DESIGN / TRADES ANALYSIS

5.1 Monopole antenna analysis

The simplest solution for our satellite is to implement a simple quarter-wavelength monopole antenna which uses the surface of the metallic cube as ground plain. This type of antenna was used in other Cubesat like Ncube (three monopole see figure 4b) or XI-V (see figure 7). The goal of this analysis is to see the impact of the placement and the orientation on the radiation pattern for monopole antenna. Two orientations are tested; the antenna is placed perpendicular or parallel on one of the satellite's face. The antenna is placed in three different positions on 0yz face (figure 4a) in order to notice the influence on the radiation pattern and to find the antenna's length which minimized the return loss (resonant frequency around 145 MHz for VHF antenna or 437 MHz for UHF antenna). The simplest solution for a deployment orthogonal to the surface is to roll up the antenna into the satellite like for Ncube (figure 4b). This system takes a lot of place in the interior of the satellite. The easiest solution from a mechanical point of view is to role the antenna on one side and to deploy it parallel to the face to save place and weight in the satellite like for XI-V (see figure 7).

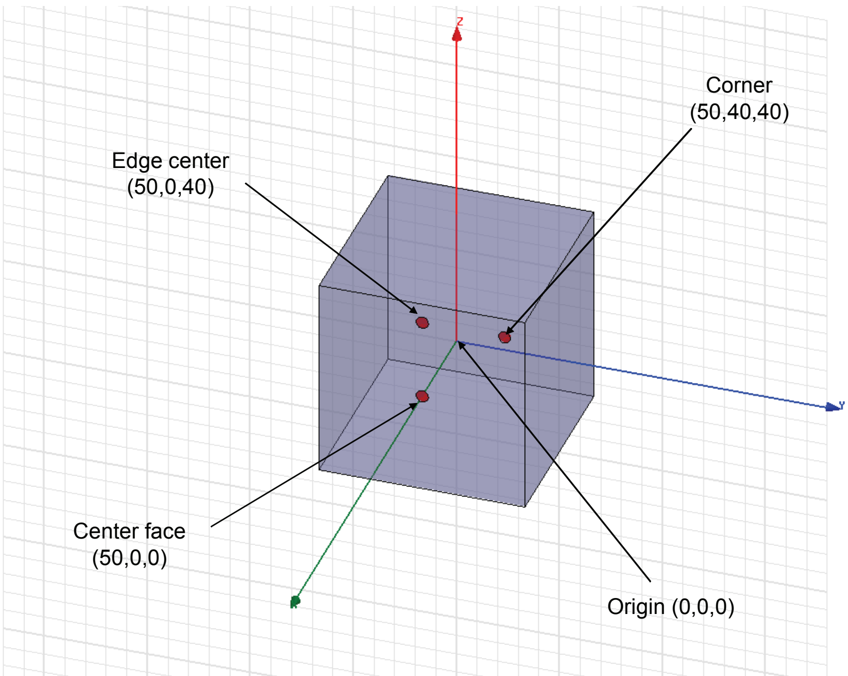


Figure 4a : schema showing coordinates and three positions of the antenna

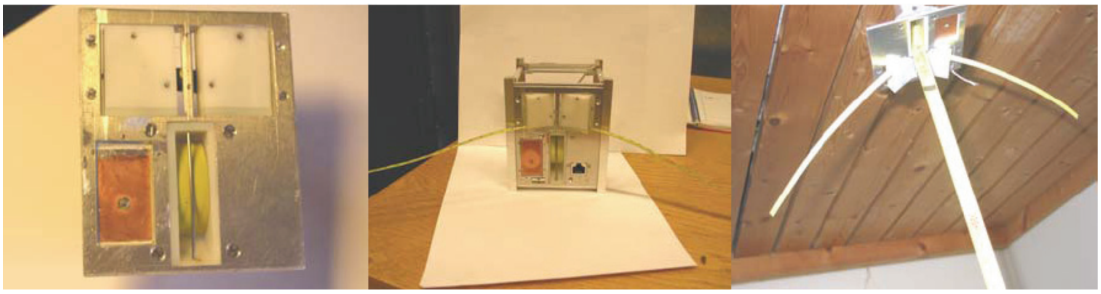


Figure 4b : Ncube with 3 monopole antennas in boxes

5.1.1 VHF monopole antenna

In case of VHF antenna, dimensions which gives the best impedance matching are in all the cases higher than the theoretical quarter-wavelength 51,4 cm, since they are between 60 cm (~0.29*λ_0) and 64 cm (~0.31*λ_0) variable according to the orientation (perpendicular or parallel) and the site of the antenna. For 145 MHz, the radiation patterns have a regular toric, with the minimum of radiation in the antenna's axis. The maximum of radiation vary lightly between 2.26dBi (~168%) and 2.69dBi (~185%) according to the orientation and the placement. The return loss varies between –16dB and –19.5dB, also only 2.5% or 1% of the signal is reflected. **In general, the position and orientation on the metallic cube does not affect too much the parameters of the VHF monopole.**

It is interesting to notice that if the VHF monopole is excited at the frequency of 437.5MHz, the radiation pattern presents two distinct lobes, because the antenna is too long for 437.5MHz, and the return loss is approximately –2dB. It means that only about 40% of power is absorbed by the antenna and 60% is reflected. All results are summarized in figure 5 where the first radiation pattern under the schema representing the satellite with antenna is for 145.8 MHz and the second radiation pattern for 437.5 MHz.

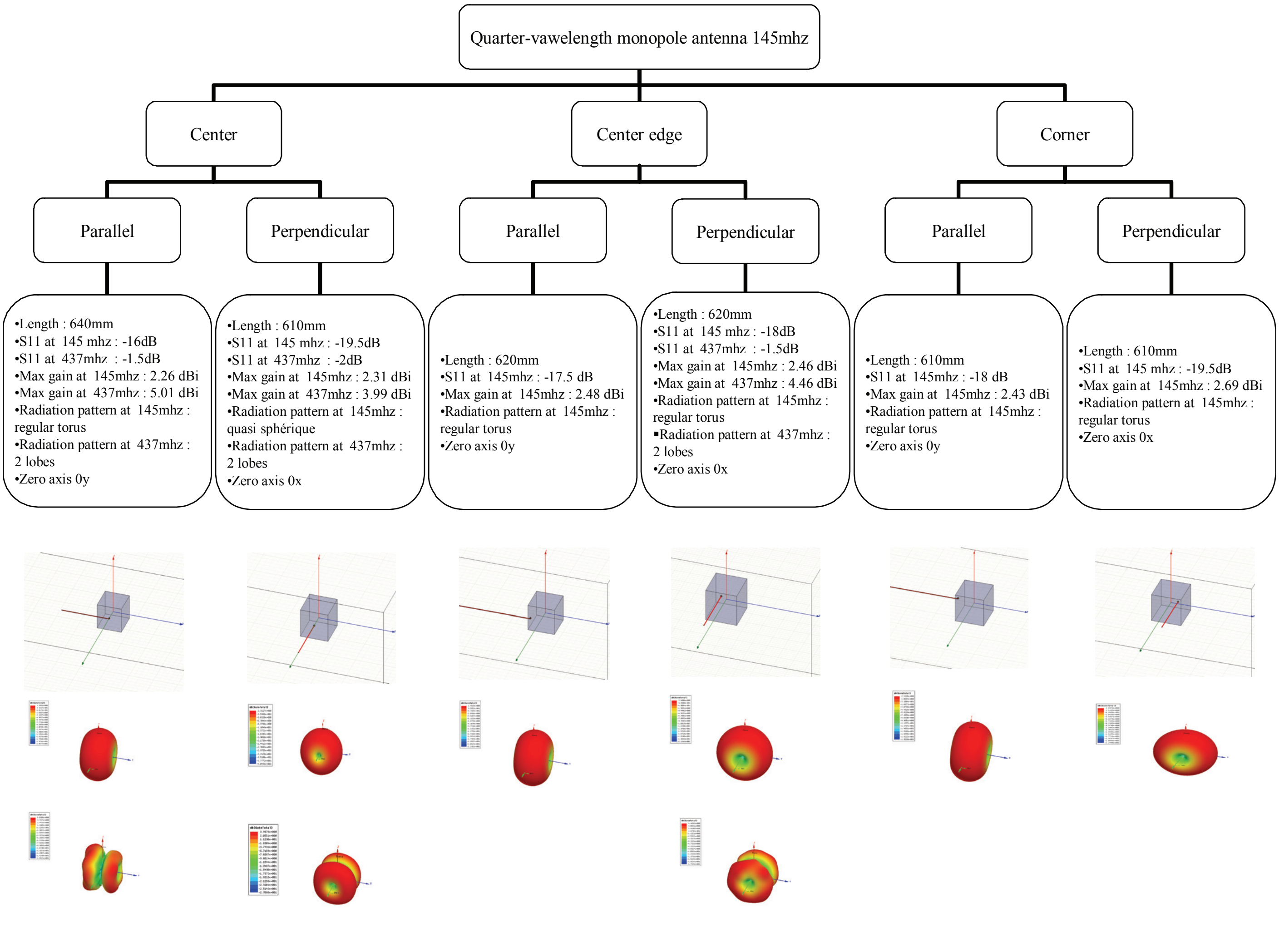


Figure 5 : trade-off tree for quarter-vavelength VHF monopole antenna

5.1.2 UHF monopole antenna

Concerning UHF monopole antenna, the lengths are very close to the theoretical dimension of 17.1 cm, they are included between 163mm (~0,237 * λ_1) and 171mm(~0,25 * λ_1) except for the parallel case at center of the face (195 mm for resonant frequency around 437MHz). The radiation patterns are rather regular and the gains are between 2.33 dBi (~171%) and 3.15 dBi (~200%), but there are more effects concerning the axis. Indeed the radiation patterns are pointing in the antenna's direction. It was not the case for the VHF antenna, the radiation patterns follow the coordinate axis (where the origin is the center of cube). The return losses are negligible around 1% or less, except for the parallel case at center of the face where s11 is -12.5 dB (17.8 % of return loss). **In general, the position and orientation on the metallic cube influence more the results than in VHF case**. All results are summarized in figure 6 where the radiation pattern under the schema representing the satellite with antenna is for 437.5 MHz.

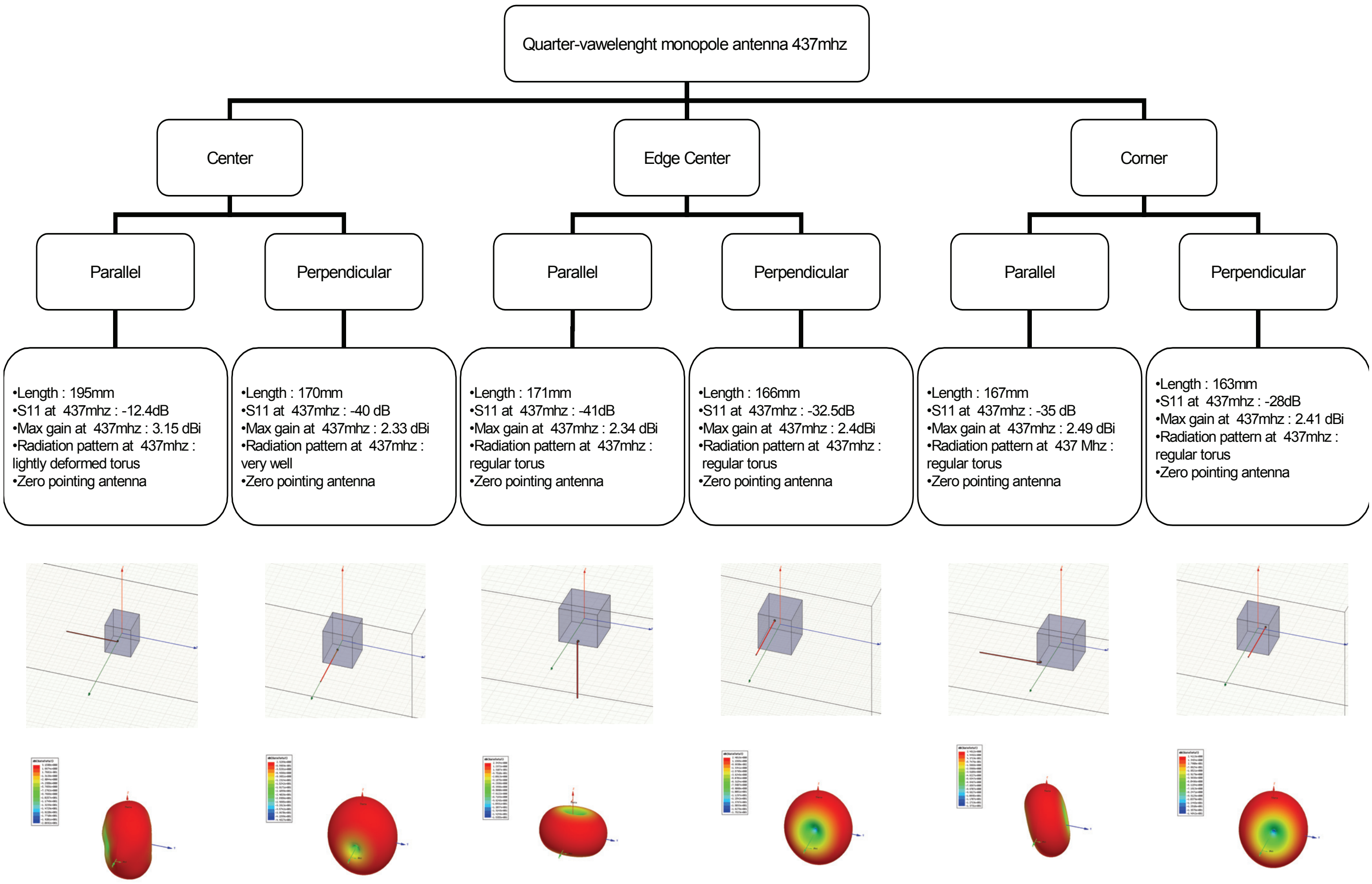


Figure 6 : trade-off tree for quarter-vawelength UHF monopole antenna

5.2 Dipole antenna analysis

The other possible solution is a half-wavelength dipole antenna, it was used previously by the University of Tokyo for XI-V (see figure 7), the University of Hawaii, the California Polytechnic State University and the University of Aalborg. The antenna is placed in three different positions on Oyz face (figure 8) in order to notice the impact on the radiation pattern and to find the antenna's length which minimized the return loss (resonant frequency around 145 MHz for VHF antenna or 437 MHz for UHF antenna). The angle between the two elements of antenna is changing to show the influence on the radiation pattern. From the mechanical point of view it's the simplest solution to role the dipole on one side and to deploy it in the plane like for XI-V (see figure 7). The other solution, more difficult mechanically is to role the dipole around the satellite like for Hawaiian Cubesat.

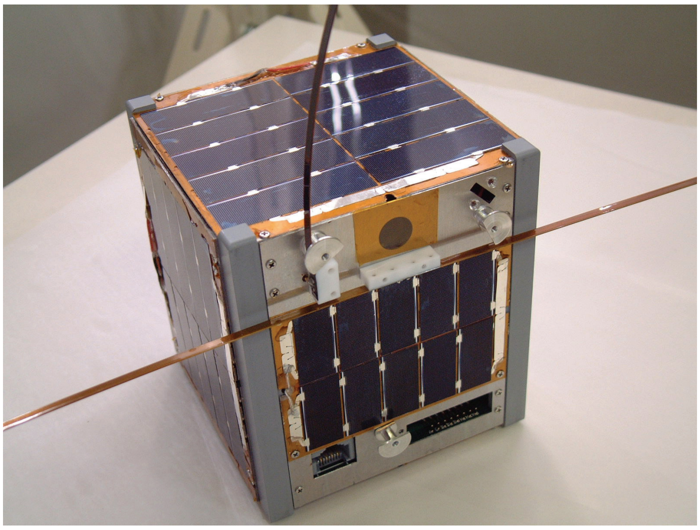


Figure 7 : XI-V with VHF monopole and UHF dipole

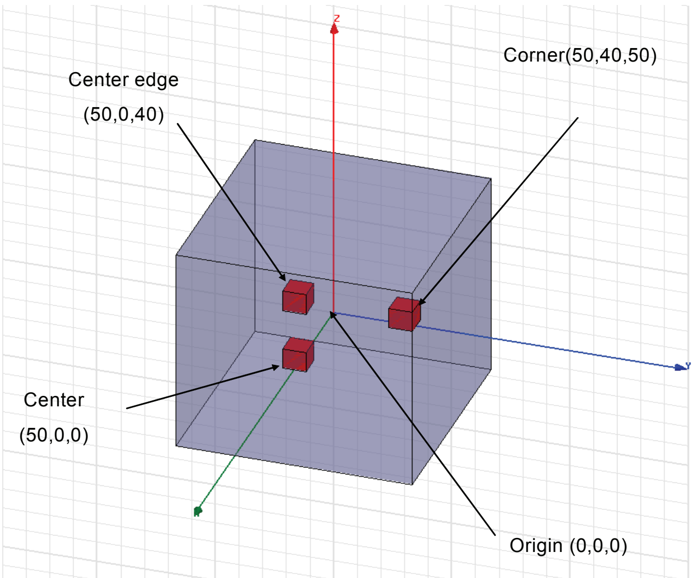


Figure 8 : three positions of the middle point antenna

5.2.1 VHF dipole antenna

In case of VHF antenna, dimension which gives the best impedance matching (100,1 cm ~ 0.49 *λ_0) is very close to the theoretical quarter-wavelength of 102,8 cm and does not vary according to the positions and the angles. For 145 MHz, the radiation pattern has in every case a toric form and does not present particular deformations. In center face and center edge positions, the axis of zero follows the coordinate axis Oy. At corner position, the radiation is directed along a transversal plan Ox-Oy. The maximum gain vary between 2.01 dBi (~158%) and 2.52 dBi (~178%) according to the geometry and the placement. The performances are a little better if the dipole is not in center of the face but in center edge. The angles between the antenna's elements decrease the max gain, but attenuate the minimum of radiation. For instance, when the dipole is flat 180°, the minimum gain is –33 dBi, and when the dipole is 150°, the minimum passes to –14 dBi. **In general, when the angle is closer, the minimum of radiation is attenuate.** The return loss oscillates between –15 dB and –24 dB, also only 3% or less than 1% of the signal is reflected. At corner position, there is an interesting case in figure 9 (corner, 180°), it presents good performance, but it is difficult to implement, because there is not enough place, the solar panels are too large 80mm x 80mm. **Finally, the metallic cube does not affect too much the parameters of the VHF dipole.**

It is interesting to notice that if the VHF dipole is excited at the frequency of 437.5 MHz, the radiation pattern presents three lobes, because the antenna is too long for 437.5MHz, the return loss is approximately –8dB, the matching is better than in case of VHF monopole antenna. Several results are summarized in figure 9, where the first radiation pattern under the schema representing the satellite with antenna is for 145.8 MHz and the second radiation pattern for 437.5 MHz.

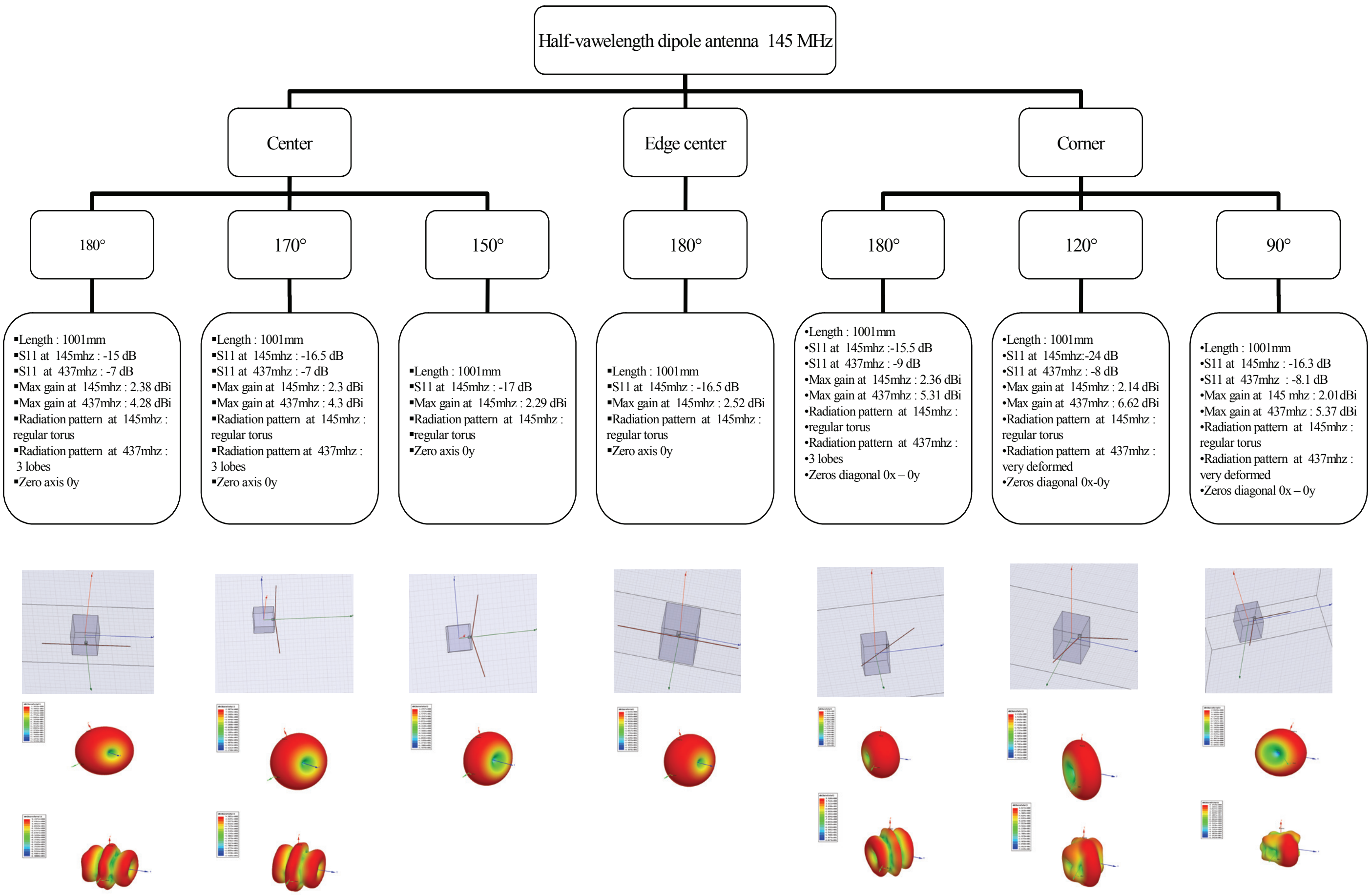


Figure 9 : trade-off tree for VHF dipole antenna

5.2.2 UHF dipole antenna

For a dipole in free space without the cube, the length of 319 mm (~ 0.46 * λ_1) presents a good value of return loss between 437 MHz (S11 of -15.47 dB at figure 2) and 438 MHz (S11 of -15.53 dB at figure 2). The radiation pattern of this antenna is in figure 1, its does not show any major deformation and the maximum gain is of 2.65 dBi.

With the cube, the dimensions which gives the best impedance matching oscillate between 353 mm (~0.51 * λ_1) with a normal geometry (angle of dipole 180°) and 330 mm (~ 0.48 * λ_1) if the antenna is at corner and the antenna forms a angle of 90°. In every case, the radiation pattern presents some less or more important deformations due to the metallic cube, it was not the case for the VHF dipole. **It indicates that the metallic cube has an important impact on the UHF dipole**. In center face and center edge positions, the radiation pattern without angle between the two elements of antenna is more uniform. In center face and center edge positions, the axis of zero follows the coordinate axis Oy. At corner position, the radiation is directed along a transversal plan Ox-Oy. It is preferable to place the dipole in edge center rather in center. When the angle between the antenna's elements is closer, the minimum of radiation is attenuate (for 180° -17 dBi and –9 dBi for 150°), but the radiation pattern becomes more malformed. The case which presents the more regular radiation pattern is at corner position with 180° angle in figure 10, but there is no place to implement this due to the large dimension of the solar panels. Several results are summarized in figure 10 where the radiation pattern under the schema representing the satellite with antenna is for 437.5 MHz.

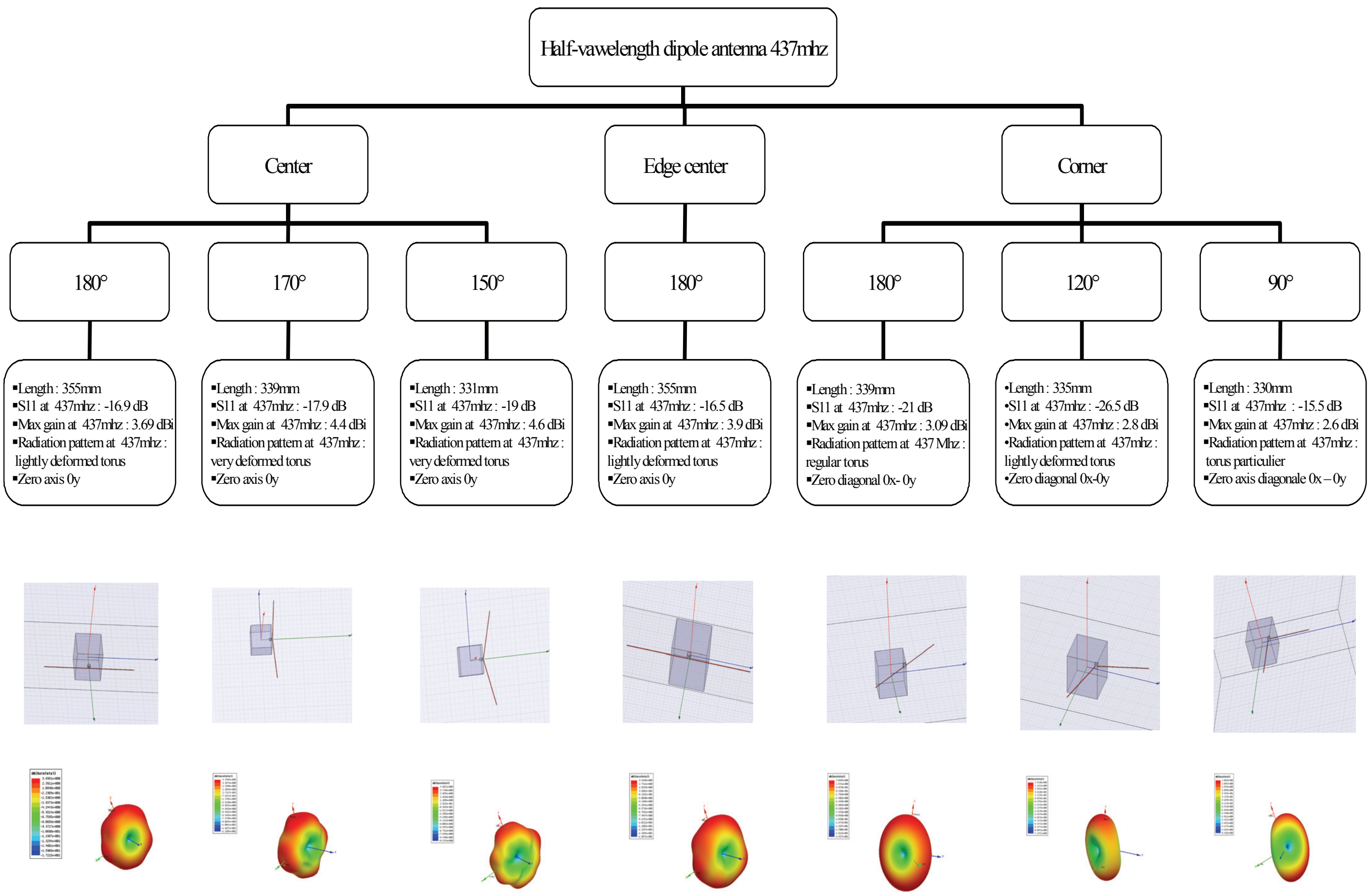


Figure 10 : trade-off tree for UHF dipole antenna

5.3 Combination of VHF and UHF monopole

The combination of two monopole antennas, one VHF and one UHF like for Ncube (figure 4b) permit to use the two frequencies at same time. In this section, the two antenna had been placed at different position to see the interaction between them, and try to determine the positions which minimize the interference.

Some technically realisable combinations between VHF and UHF dipole have been simulated. The most simple case to implement mechanically is two monopole antennas parallel to a face. At first look, it seems to be necessary to have the two antennas orthogonal, because it reduce the interaction. For instance, if the angle between the antennas is 45° like in figure 11, the radiation pattern for VHF antenna stays normal, but the radiation pattern for UHF monopole become very malformed (figure 12). When the antennas are orthogonal, the radiation pattern for UHF antenna become again normal, like in figures 13 and 14.

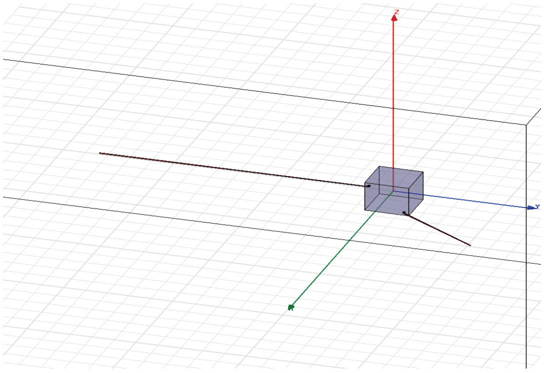


Figure 11 : 45° between antennas

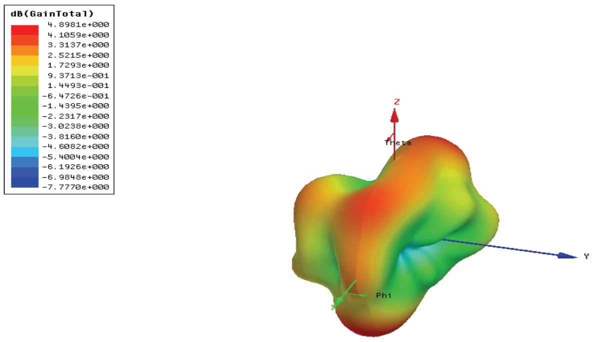


Figure 12 : radiation pattern at 437.5 MHz for figure 11

According to small dimensions and available space, the use of two faces does change something compared to one face (compare figure 13 and 14, in general S21 parameters are better with only one face than with two). Probably, only one face will be available to place the antennas.

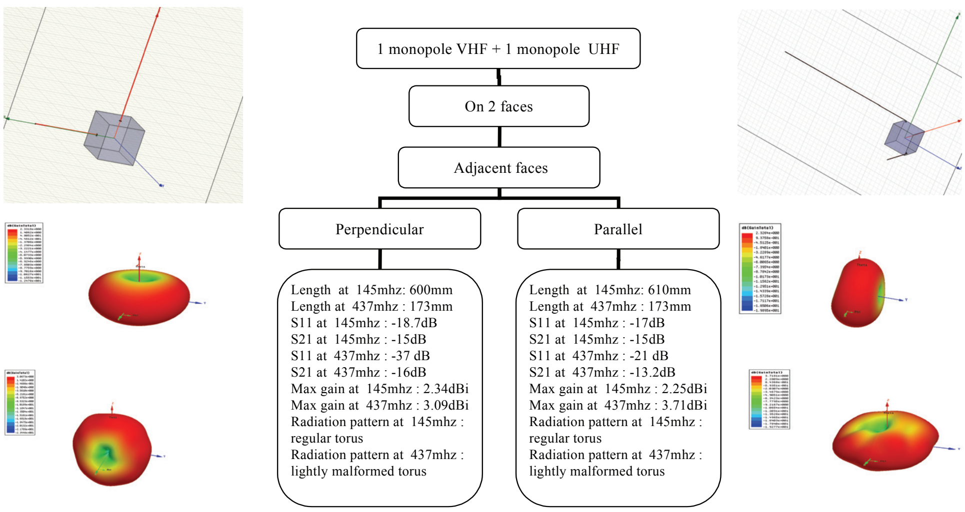


Figure 13 : trade-off tree for two antennas on two different faces

In every case, the VHF antenna have a deep impact on UHF antenna, because the UHF radiation pattern becomes malformed and the UHF gain increases in figure 14 compared when it is alone like in figure 6. But, the UHF antenna does not disturb the VHF antenna, the max gain stays in the same range and the radiation pattern is always regular.

It's difficult to conclude something, because the antennas are very close and each antenna is in the fare field of the other. Indeed, for the tested cases in figure 14, the s21 parameter (coupling) is lower when the antennas are closer one the same face. The results of treated cases are summarized in figure 14, where the first radiation pattern under the schema representing the satellite with antennas is for 145.8 MHz and the second radiation pattern for 437.5 MHz.

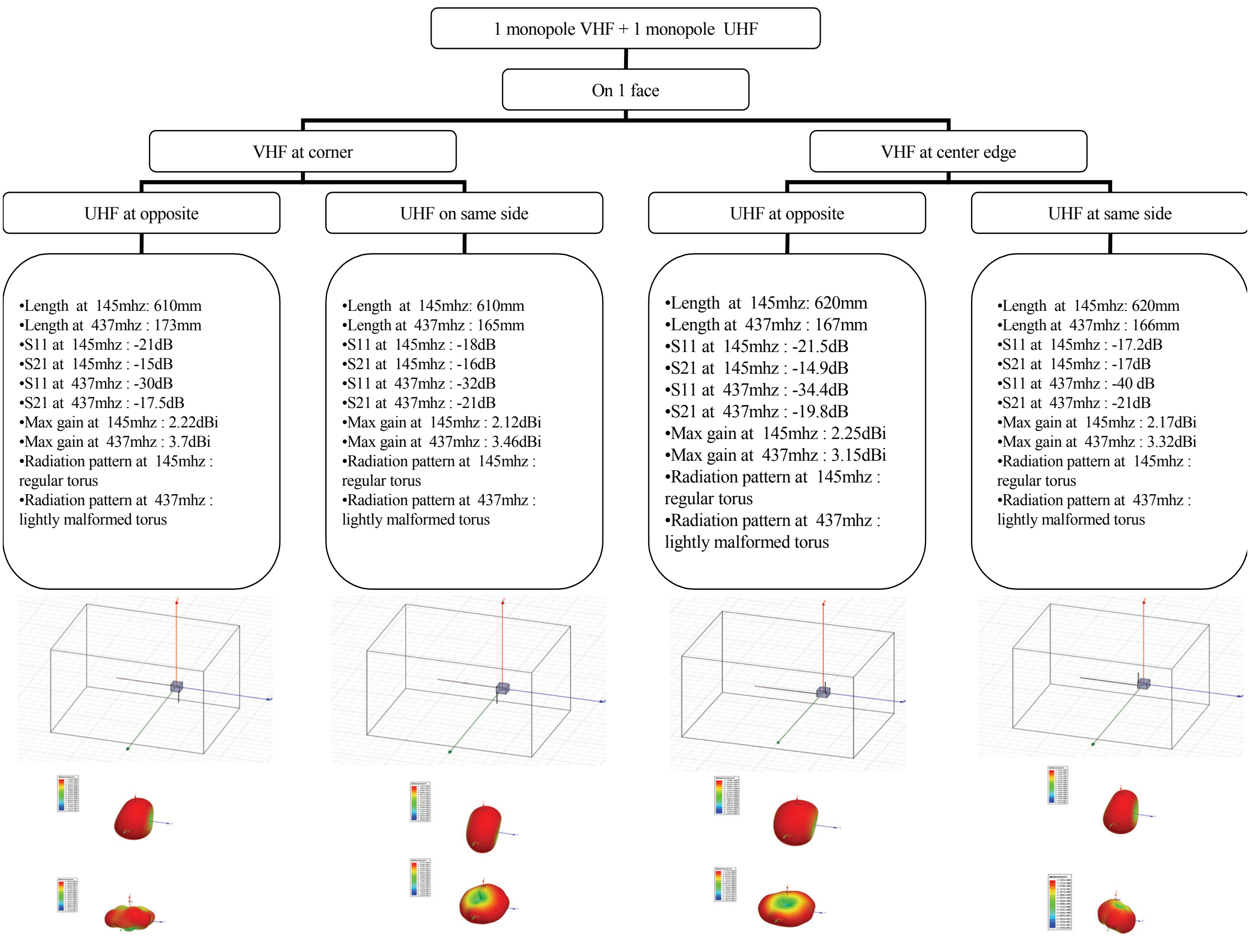


Figure 14 : trade-off tree for two monopole antennas on the same face

5.4 UHF dipole and VHF monopole

An other interesting case which is not too difficult to implement is to use one VHF monopole and one UHF dipole like used for XI-V (figure 7). In this section, the two antenna had been placed at different position to see the interaction between them, and try to determine the positions which minimize the interference.

The two antennas are orthogonal to minimize the interaction between them. Three different cases for a UHF dipole (353 mm) and a VHF monopole (610mm) are tested, the VHF monopole is placed at corner to simplify deployment and the UHF dipole is moved at three different positions. The distances between the antennas are respectively 8cm, 4cm and 5mm in figure 15.

The results are logical, it gives better performance for each antenna in term of gain, s11 and s21 when the antennas are far one from the other. The UHF antenna doesn't have a deep impact on the VHF antenna, but VHF have a real influence on UHF antenna. Indeed, the radiation pattern for VHF antenna is very regular like when the VHF antenna is alone, the value of gain does not change in large proportion. But, for UHF the radiation pattern are malformed, and max gains are increases in the first two cases compared to the UHF dipole alone (figure 10), but decreases when there is only 5mm between the antennas. The results are summarized in figure 15 where the first radiation pattern under the schema representing the satellite with antennas is for 145.8 MHz and the second radiation pattern for 437.5 MHz.

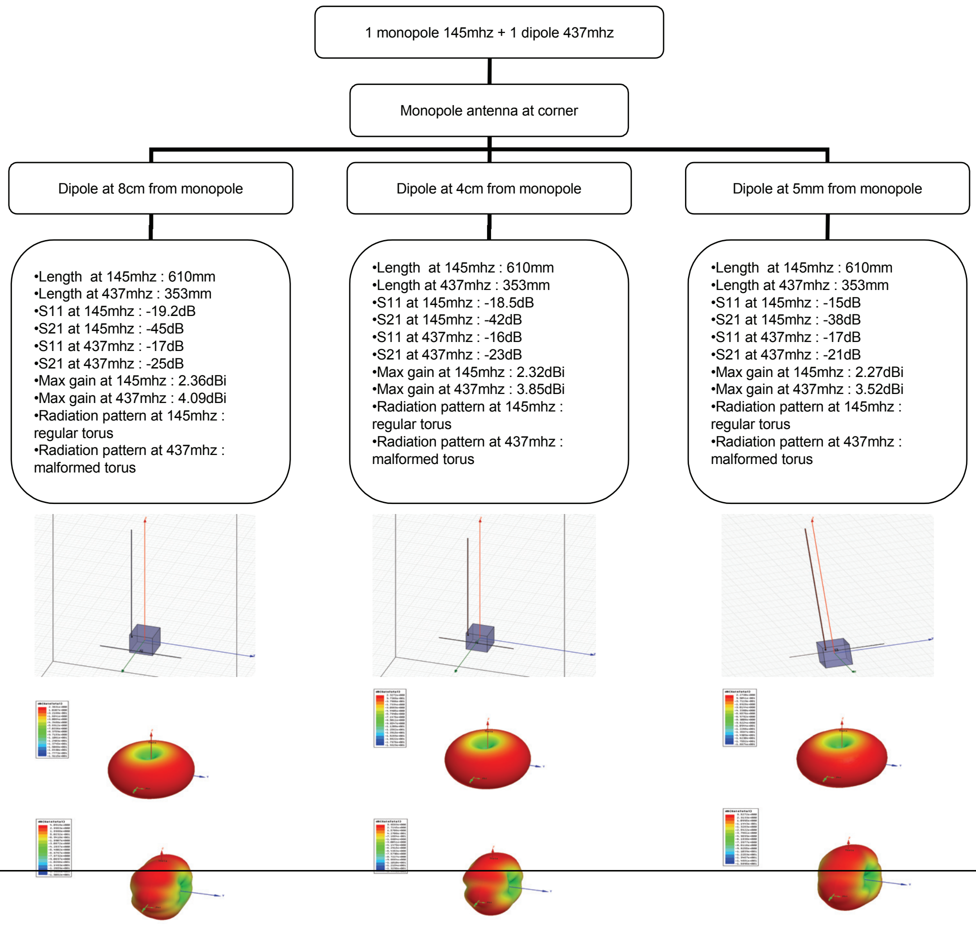


Figure 15 : UHF dipole and VHF monopole at corner

In figure 16, the VHF monopole is placed at corner position and UHF dipole is placed at three different sites like previously. The results are less obvious, the S21 is very low in each situation and decreases lightly from –60 dB to –50 dB. For UHF antenna, the gain is better if the antenna is very close 5mm or very far from the VHF antenna. It's difficult to conclude something, because the antennas are very close and each antenna is in the fare field of the other. The results are summarized in figure 16 where the first radiation pattern under the schema representing the satellite with antennas is for 145.8 MHz and the second radiation pattern for 437.5 MHz when the VHF monopole is at corner and the dipole change his position.

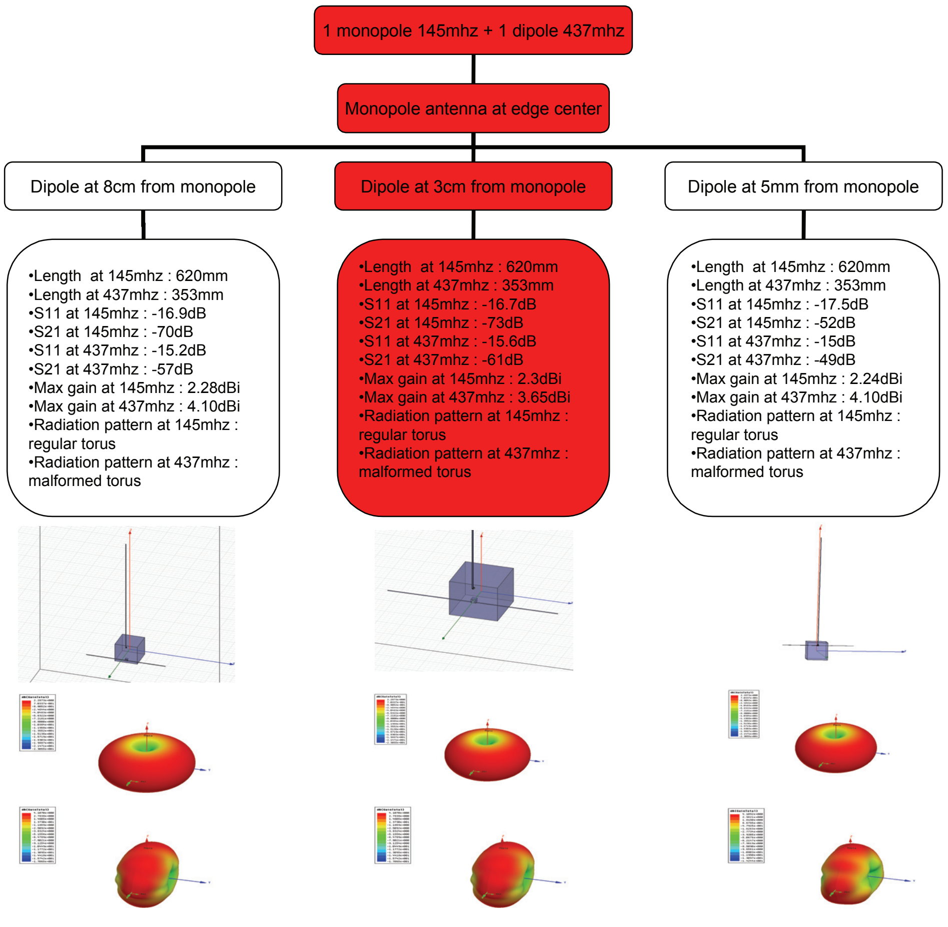


Figure 16 : UHF dipole and VHF monopole at center edge

5.5 Comparison between one (figure17) and two antennas (figure18a) options

One VHF antenna (for the two frequencies) advantages :

+ Deployment
+ Space used for antenna
+ Zero signal in same axis

One VHF antenna (for the two frequencies) disadvantages :

- Weight : need diplexer UHF/VHF
- Half duplex
- Radiation pattern non-uniform for UHF mode (two or three lobes, see figure 5 and 9)
- Important power reflection in UHF mode : need impedance matching

One VHF and one UHF antennas advantages :

+ Weight
+ Full duplex (but not needed)
+ Radiation patterns uniform for UHF and VHF
+ Low power reflection in VHF and UHF

One VHF and one UHF antennas disadvantages :

- VHF antenna influence on UHF antenna : coupling
- Deployment
- Space used for two antennas
- Zero signal in different axis

Choice for baseline : two antennas

5.6 Comparison between dipole and monopole

Monopole advantages :

+ Weight and length
+ Space
+ Deployment

Monopole disadvantages :

- Minimum signal in antenna axis

Dipole antenna advantages :

+ Two elements geometry can attenuate minimum signal

Dipole antenna disadvantages :

- Weight and length
- Space
- Deployment
- Need balun for symmetric excitation

Choice for baseline : a monopole for UHF and a dipole for VHF

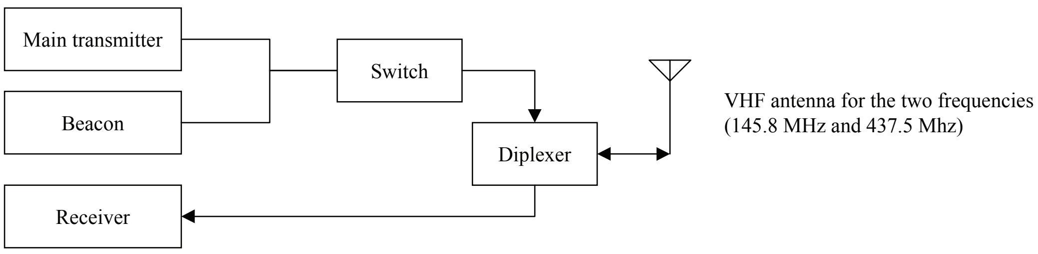


Figure 17 : block diagram for one antenna option

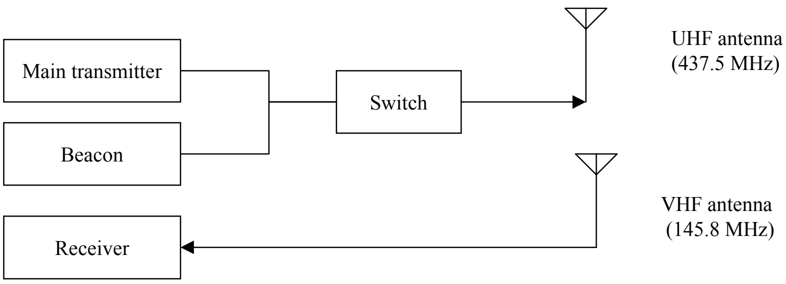


Figure 18a : block diagram for two antennas option

5.7 Material

In other Cubesat Project, the antennas are often made of beryllium copper. This material presents three advantages :

- Excellent electrical conductivity
- Combination of low modulus of elasticity and high ultimate tensile strength
- Non-magnetic material

Density of beryllium copper is about 8.9 gr/cm3. The mass budget for antenna and deployment mechanisms mustn't excess 29 gr.

6 BASE LINE DESIGN/ RECOMMENDATIONS

Finally, referring to the comparison in section 5, we choose to use a quarter-vawelength monopole antenna for 145.8 MHz and a half-vawelength dipole antenna for 437.5 MHz like illustrated in figure 18b , 19 and 16 (the case at the middle). To have the best results in term of performance, the antennas should be in plane parallel to the earth's surface.
Obviously, there are a lot of constraints due to the mission's objectives (the side with the camera objective has to be orthogonal to the earth's surface), the chosen configuration (the only face without solar panel is where the camera is) and the deployment reliability and weight (antenna can only be deploy parallel to the face where the camera is). This configuration implies that an antenna should be pointed to the earth's center in way to be orthogonal to the other antenna to minimize the coupling. Indeed, due to the deployment reliability and weight, it was impossible to put this antenna orthogonal to the camera's face

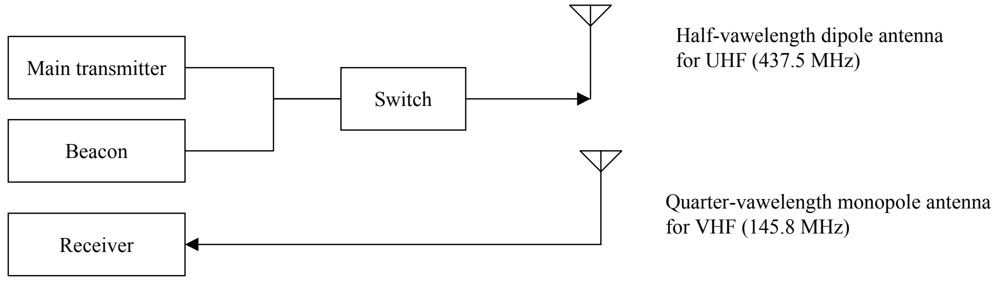


Figure 18b : block diagram for the chosen baseline

6.1 Baseline design

The design presented in figure 19 was made in collaboration with "Antenna deployment" (see Appendix A for detailed drawing prototype) to be compatible with available space on face with camera and mechanical limitations. The disadvantage of this configuration is that the VHF antenna was pointed at earth's center and it was thought that it could be a problem when the satellite was near the ground station at EPFL with connection loss (ground station antenna and VHF monopole of the satellite are in same axis). The radiation patterns related to figure 19 for each antenna are presented in figure 20 and 21. In fact it corresponds to the red case in figure 16.

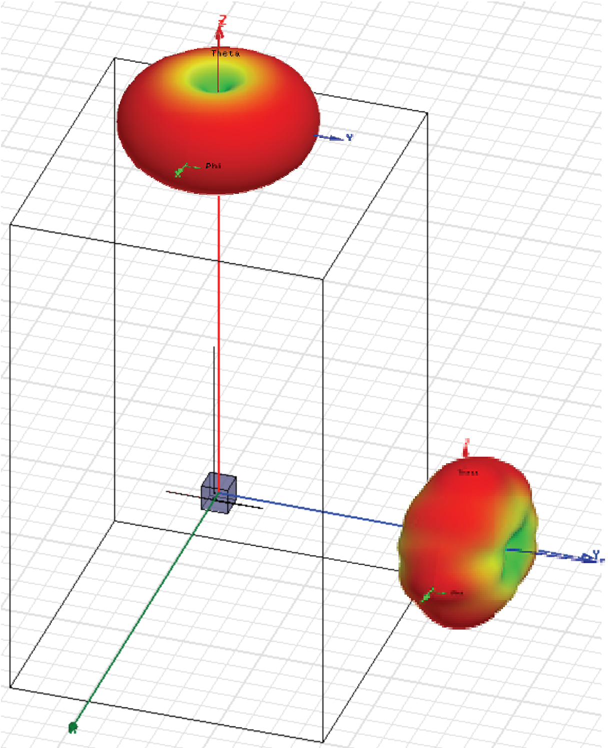
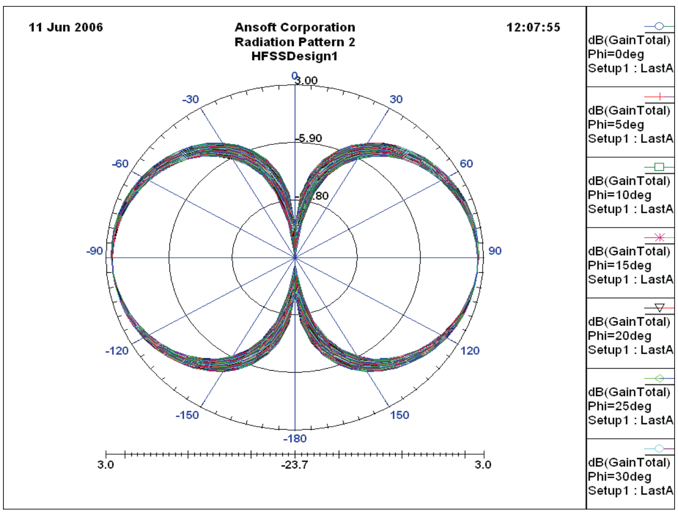


Figure 19 : the first configuration for antenna with monopole pointed to earth's center



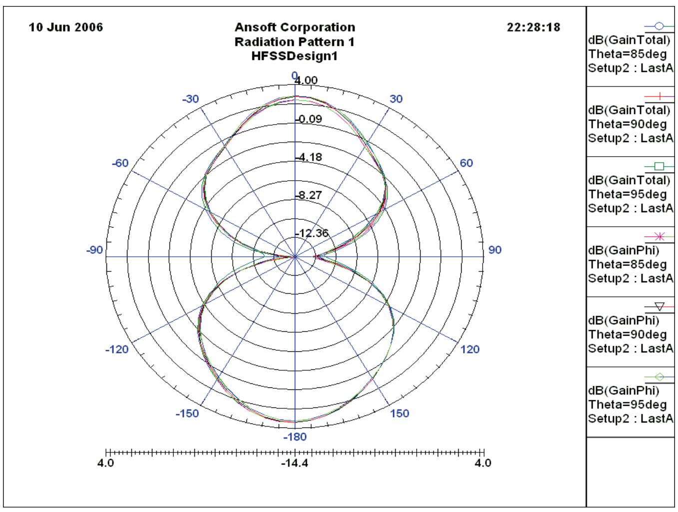


Figure 20 : radiation pattern for VHF monopole

Figure 21 : radiation pattern for UHF dipole

6.2 Recommendation

In way to attenuate the minimum at center of radiation pattern, it is tried to give an angle of 120° between the elements of UHF dipole antenna and to inverse the VHF and UHF antenna (figure 23).

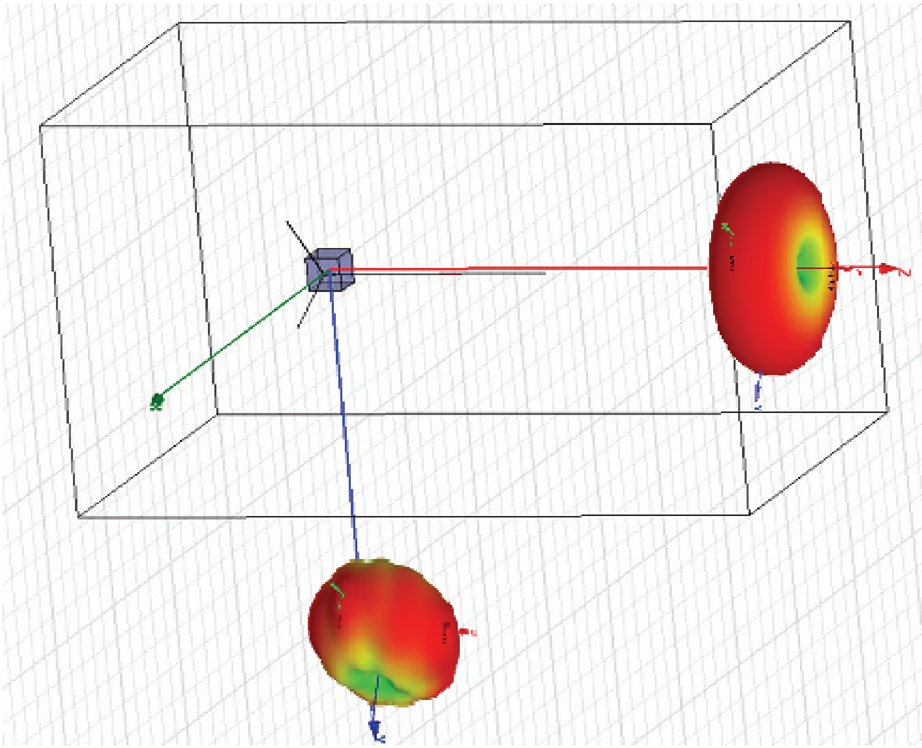


Figure 23 : UHF dipole with 120° pointed to earth's center and VHF monopole tangent to earth's surface along red axis

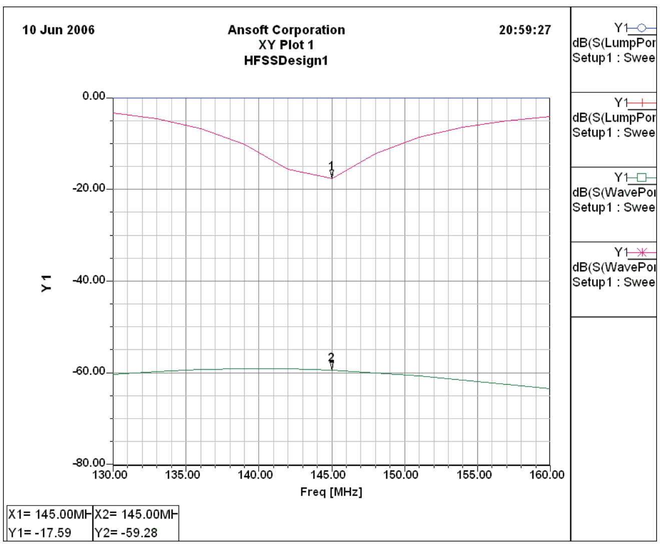


Figure 24 : S-parameters for VHF

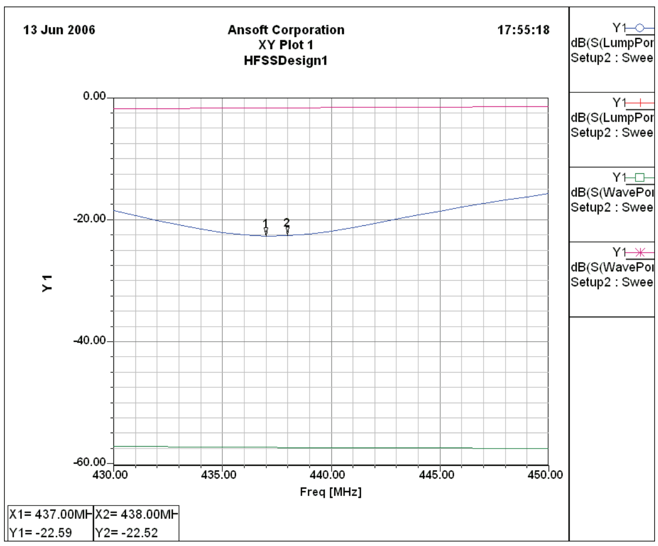


Figure 25 : S-parameters for UHF

The S-parameters related to figure 23 are presented in figure 24 and 25 (blue line S(lumpedport1, lumpedport1), red line S(waveport1, vaweport1), green line S(vaweport1,lumpedport1), where vaweport1 is used by VHF monopole and lumpedport1 is used by UHF dipole). The radiation patterns for figure 23 are in figure 26 and 27. In figure 23, the dimensions of antennas are 630 mm x 3 mm x .03 mm for monopole and (2 x 184 mm) x 3 mm x 0.3 mm, they are placed near center at 1mm from the surface of the cube. The maximum gain for UHF dipole decreases from 3.65 dBi to 3.31 dBi compared to the configuration in figure 19, but the minimum passes from –14.4 dBi to -7.5 dBi. It's more favourable when the Swisscube is just above the EPFL.

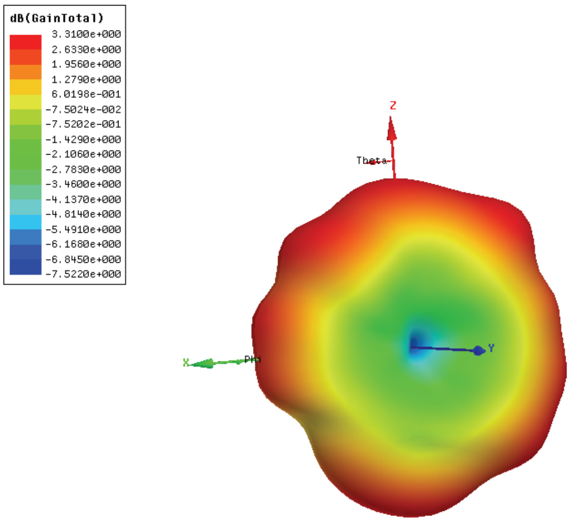


Figure 26 : 3D radiation pattern for UHF dipole

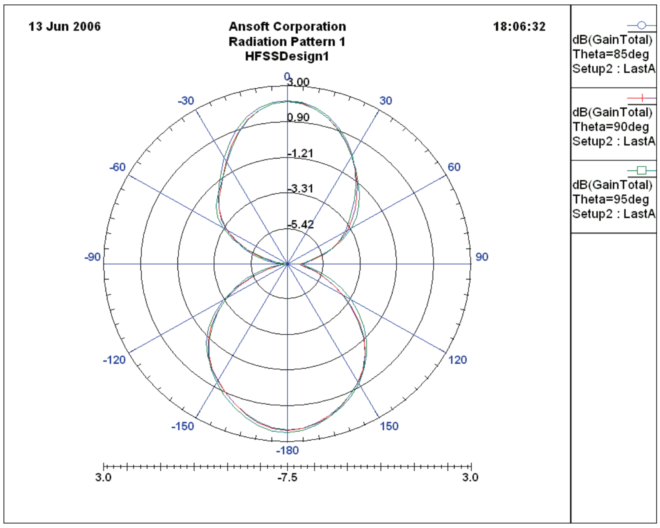


Figure 27 : 2D radiation pattern for UHF dipole

6.3 Mass Budget

A word about mass budget, in this second configuration (section 6.2), the weight of antennas made of beryllium copper are 5 gr for VHF monopole and 3 gr for UHF dipole, but the dimensions can change in practice. But, in practice dimensions of the antennas can be different from the dimensions of the simalations, also the mass of antennas can be variable. The antennas can be mounted to the coaxial cables using SMA-connectors. This is however unnecessary, the coaxial cable can be mounted directly onto the antennas. This will save weight which is a precious ressource on the SwissCube satellite.

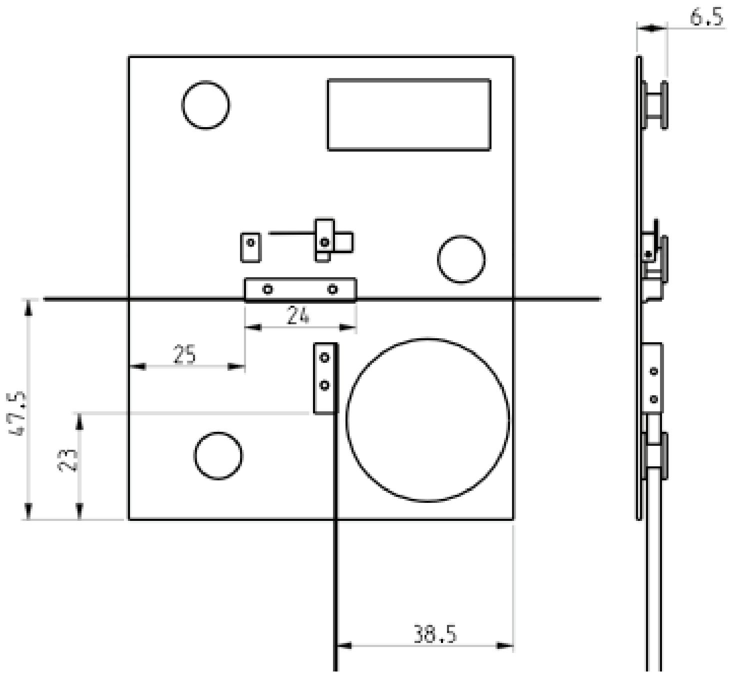
Mass budget:	(in g)	
•Mono&Dipole	8	
•2 connectors	3	estimation
•Cables	3	estimation
•3 Polymer fixations	1.225	
•3 points of contacts (Aluminium)	1.14453	
•10 screws	2	estimation

•Melting wire fix	1.5	estimation
Total:	19.86953	
Additional weight (not our subsystem)		
•2 Kill switches	10	literature
•1 Aluminium panel for prototype mounting	27	
Total:	37	

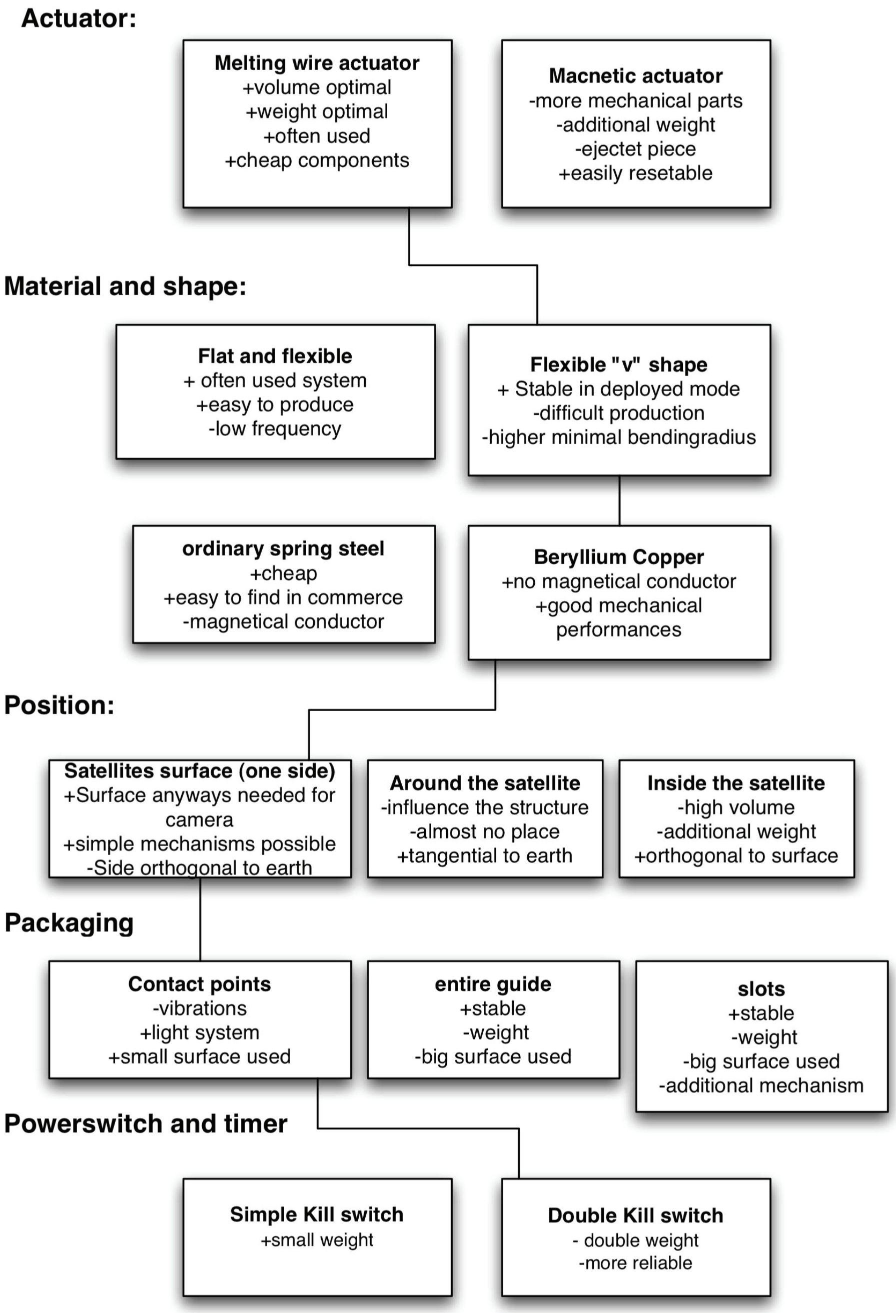
7 CONCLUSION

The conception of this satellite is a very interesting project, but the difficulty is to find a good compromise between each subsystem, what can be hopeful for the antenna subsystem may disturb or be in contradiction other subsystem like altitude control, antenna deployment, science observation. The proposition in section 6.2 is not optimal, but with the limitations of weight and space for the deployment system it's difficult to do better with two antennas, since it seems to be impossible to put the VHF monopole antenna orthogonal to the camera's face. This would be only possible by rolling up the antenna into the interior of the Cubesat. During the decisions for a baseline of phase A the place in the interior was very limited and this solution was not possible. If the place conditions are changing, this solution should be taken into consideration. Another possible solution will be to use only one VHF antenna with a VHF/UHF diplexer, but it's not sure that it will resolve better the problem, the known Cubesat which use UHF and VHF frequencies have usually 2 antennas like for the Ncube, XI-IV and XI-V.

Appendix A Drawing prototype by Mario Greber



Appendix B Deployment system chosen by Mario Greber



Appendix C Bent dipole by Guillaume Roethlisberger