2010

I2’s Internship

Internship at the MS&T University of Rolla

I am doing my I2’s technical internship in the United States at the University of Science & Technology in Rolla (Missouri 65401).
We have been working in the laboratory of this University in new electronics technologies.

Louis PARENT
ESEO
04/09/2010

Acknowledgement

The special thanks goes to my helpful supervisor, Dr. Richard E. Dubroff. The supervision and support that he gave truly helped the progression and smoothness of the internship program. The co-operation is much indeed appreciated. He was our contact when we were in France and in the laboratory. Without him, we would never have been in this Lab.

My grateful thanks also go to Dr. Pommerenke. A big contribution and hard work from him during this internship is very great indeed.

All projects during the program would be nothing without the enthusiasm and imagination from the people who work in the lab. Besides, this internship program makes me realize the value of working together as a team and as a new experience in working environment, which challenges us every minute. Moreover, great appreciation goes to the rest of Lab's staff that helped me from time to time during the project. The whole program really brought us together to appreciate the true value of friendship and respect of each other.

I also would like to thank Mr. Ramdani and Mr. Perdriau for helping me find this internship. They were present all the year for us.

I. Table des matières

II. Introduction

I am going during three months, for my technical internship, with three other ESEO's students (Kevin Guillemet, Jérémy Brunet and Arnaud Royer) in a Lab of a University in the United States.

This University is called Missouri Science & Technology.

Here is the address and phone numbers:

> **Missouri University of Science and Technology**
> **1870 Miner Circle**
> **Rolla, MO 65409**
> **+1-(573)-341-4111 | +1-(800)-522-0938**

We were welcomed by Dr. Richard E. DuBroff, a Professor who works in the lab. And he was our contact when we were in France.
This lab is an Electromagnetic Compatibility laboratory.

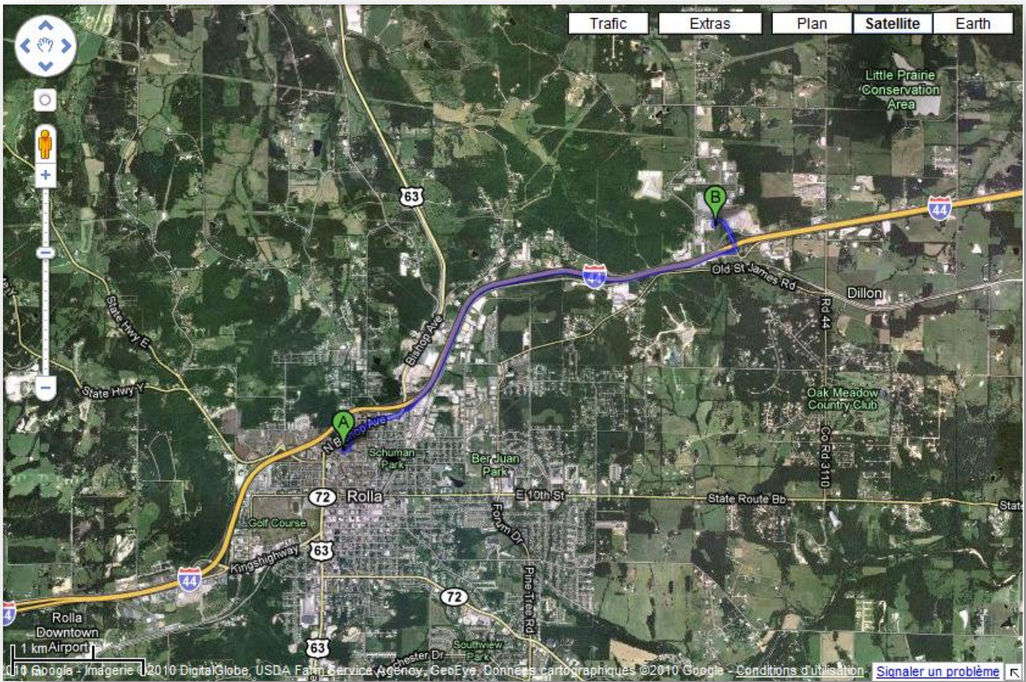
Here is the address, phone number and E-mail:

> **EMC Labotory**
> **4000 Entreprise Dr.**
> **Missouri University of Science and Technology**
> **Rolla, MO 65401**

During three months, we worked on several small-projects in electronic (Crosstalk, Apple Project, RED Project…).

Picture of Google Maps:

in A MS&T and in B EMC lab



III. Presentation

You will find in this part, a presentation of the university, the lab where we have worked during these three months, important people in the lab and an enumeration of our projects during our internship.

A. The University

1. Historic of the MS&T University

The Missouri S&T (MS&T) was founded in 1870 and it was the first technological learning institution west of the Mississippi. At the debut, the University was called “Missouri School of Mines and Metallurgy” (MSM). It’s only in the 1920s that the University had expanded into other specialties like electrical, civil, mechanical and chemical engineering.

The name was changed in 1964 when the university was expended at other type of sciences, like arts, psychology and history.

The final name was attributed was Missouri University of Science and Technology also called Missouri S&T (MS&T). It was renamed on January 1, 2008.

Today, the University is known for the engineering school, but also for a lot of other sciences (Humanities, Business, Social Sciences, Sciences, arts).

You could find all information about the university in his web site:

http://www.mst.edu/

You could see here “the University of Missouri” seal.

2. Generalities

You will find in the annex a map of the University. (**Annex 1**)

This university is a University of Science and Technology. During the school year, it welcomes more than 6,815 students in 2009.

Rolla is a small town of 17,000 inhabitants. it is a university town. Without students, Rolla could not be what it is.

All the university is for the students, it is giant. MS&T is like a small town with in Rolla. You could find a lot of shops to buy everything about the university (T-shirt, accessories, sport's shop…). There is a bookstore too, in which you could by all in electronics. It works with Apple. A lot of market is around Apple in this place. In the campus, the Havener center is the principal building. Inside you can find banks, restaurants, bookstore, and the reception.

External picture of the Havener center of the University of MS&T

3. Technology

But this University is especially known for its learning and its modernity. There is a lot of modern material and advanced technology.

You could read on http://futurestudents.mst.edu/explore/technology.html a description of this:

> ***"Missouri S&T does have modern classrooms, big and small, but a lot of the learning takes place in laboratories all over campus. Learning through experimentation is encouraged, and all students, including undergrads, have opportunities to work on research with professors.***
>
> ***Students have access to the best faculty, the most modern facilities and the latest equipment. In addition to laboratories of various kinds, the campus has widespread wireless access, high-speed Internet, technology-enabled classrooms, computer learning centers and state-of-the-art distance learning classrooms. As a student, you'll have access to some of S&T's coolest toys: multi-million dollar microscopes, water-jet technologies, digital flow laboratories, massive computing networks, and more."***

Here you see an electronic microscope

A lot of groups come here to use the high technology offered by this University. A lot of people around the United States, and around the world come to Rolla for its advanced technology. There are a lot of Japanese and Chinese in this town. The University is very attractive for many people who want to use new and advanced technology.

4. Activities

Sports are very present in student life. Most of them are in a student organization during the year and they are active participants in this community. That is very important for students.

a) Student life

Football with students at the University MS&T's Rolla.

Communities

A lot of events are organized and included in the calendar of the campus. The University has a student council, a newspaper published every Thursday during the school year called *"The Missouri Miner"* since February 2007.

There are two radio stations on the campus, KMNR and KMST. And one amateur radio station founded in 1931. This last radio runs with the amateur radio club of the University.

The university and this club organized a lot of sports events in the year. There are over 200 student organizations at MS&T. You could play nineteen different sports in this place.

On the campus, there are four sororities and twenty three fraternities.

b) *Student engineering projects*

During the year, a lot of projects and many activities are done by students. The most popular are:

- **Show-Me Solar Team**

This project is an environmental project. The team designs and builds a house, which is completely sustained by solar energy. There are a lot of solar panels around this build. The purpose of this construction is to invent and create a house totally clean for our environment.

- **Advanced Aero-Vehicle Group**

“The team constructs a remote controlled airplane for the annual Society of Automotive Engineers' Aero Design competition.” (Source: Wikipedia)

- **Human Powered Vehicle**

“The team promotes alternative energy technology while providing tomorrow’s engineers with hands-on experience in applying classroom knowledge.” (Source: Wikipedia)

- **Formula SAE Car**

“Missouri S&T's Formula SAE team constructs a small formula-style race car every year, suitable for mass production and sale to weekend autocrossers.” (Source: Wikipedia)

- **Concrete Canoe**

“Missouri S&T's Concrete Canoe Team designs and constructs a concrete canoe and races it on a lake in regional and national competitions.” (Source: Wikipedia)

- **Solar Car**

“Every two years, the team constructs a single-passenger car, its top covered with gallium arsenide solar cells that runs exclusively on solar power. “(Source: Wikipedia)

The last car was here during our internship. It was very impressive to see this project.

You could see here the solar car 2010, “Solar Miner VII”

- ### Robotics Competition Team

"The team builds autonomous vehicles that traverse obstacle courses consisting of lane markers and obstacles." (Source: Wikipedia)

- ### Mine Rescue Team

"Missouri S&T is home to the only Mine Rescue Team made up entirely of college students. The team competes regularly against professionals in simulated mine disasters." (Source: Wikipedia)

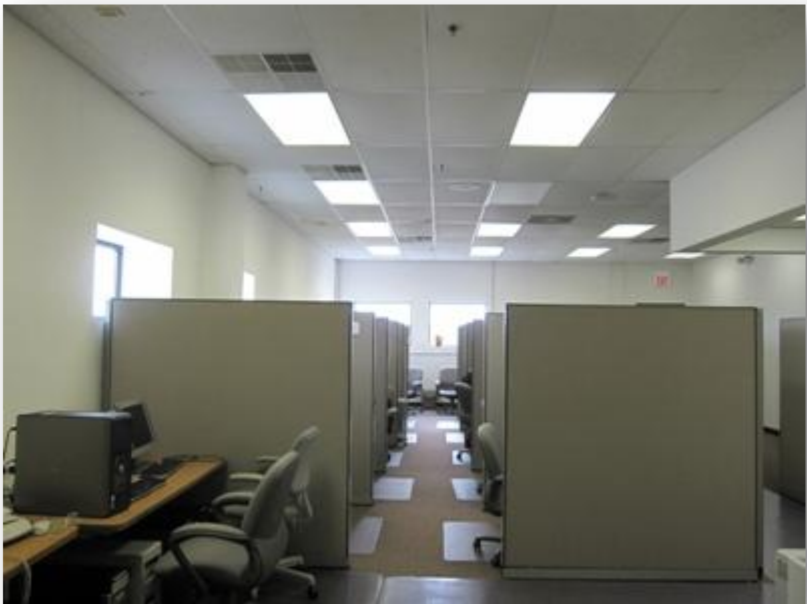
That is a presentation of the University. It is well known in the United States in the field of electronics and new technology. It is impressive to see the advanced capabilities of the American universities. It is so different from French school and French campus.

Now I would like to present the lab where I have worked during my technical internship.

B. The EMC (Electromagnetic compatibility) lab

The EMC laboratory is one of the most well known electromagnetic labs in the world. In this lab, a lot of people come work for its prestige. We have worked with German, Chinese, Russian, and Japanese people. It was so interesting to learn with people who come from around the world.

The main entrance to our laboratory facility



In the lab we have office space conveniently located near the labs. Each student has a private cubicle space and a networked computer.

We have worked all our internship in the experimental work area. In this place we find all the material required to work on our project.

Experimental work area

In this lab, you can find two Semi-Anechoic chambers used to make radiated emissions and susceptibility measurements, as well as to provide a relatively noise-free environment for other measurements.

This Lab is equipped with important instrumentation like 50 GHz vector network analyzer, 50 GHz spectrum analyzer, and micro-probing station. And we have worked or seen work a lot of these instruments.

One Semi-Anechoic chamber

At this time, the lab works with a lot of big companies and on a lot of projects. You can see here their recent or current research projects:

- Printed Circuit Power Bus Design and Modeling
- In-Board Low-Pass Filtering
- Enclosure Design for EMI
- EMI Expert System for PCB Design Analysis
- Differential Clock Driver Evaluation
- Differential Signal EMI
- EMI Associated with Inter-PCB Connections
- PCB layout Strategies for Low-Cost Boards
- Chip-Level EMI Investigation
- A System-Level EMC Expert System for Automotive Designs
- Development of Numerical Modeling Codes for Solving EMC Problems
- Electrostatic Discharge Susceptibility of Computer Peripherals
- Repeatable Electrostatic Discharge Tests

You can find more information about the lab on this website:

http://emclab.mst.edu/

IV. Projects

We have worked on several projects. In this part I would like to explain what our projects are. Generally, we have worked in a group of two students. For the report, I will speak about all the projects and explain in more detail my contributions.

Most of the time, I was working with Arnaud Royer.

During three months in the lab, three major projects were assigned to us. The most important of them was the project RED; we began this project upon our arrival in the lab, and it was finished by the end of the three months. This project is our first project and the most important.

Two other projects were assigned to us, but we have worked on this just during a short time. We have helped Kèvin Guillemet and Jérémy Brunet in the Cross Talk Project to make some measurements and realized a model of this one.

Our third project was a project with Apple. We have worked to find a solution for batteries of new Apple projects.

A. The Sphere project, Real-Time 3D Electromagnetic Field Display (RED) project

1. Presentation of the project

Sphere's project is the first one. Dr. Pommerenke gave us this project when we arrived in June. The goal of this project is to model the wave fields emitted by an antenna. We use a 900 MHz frequency because this one is the frequency used by most of GSM.

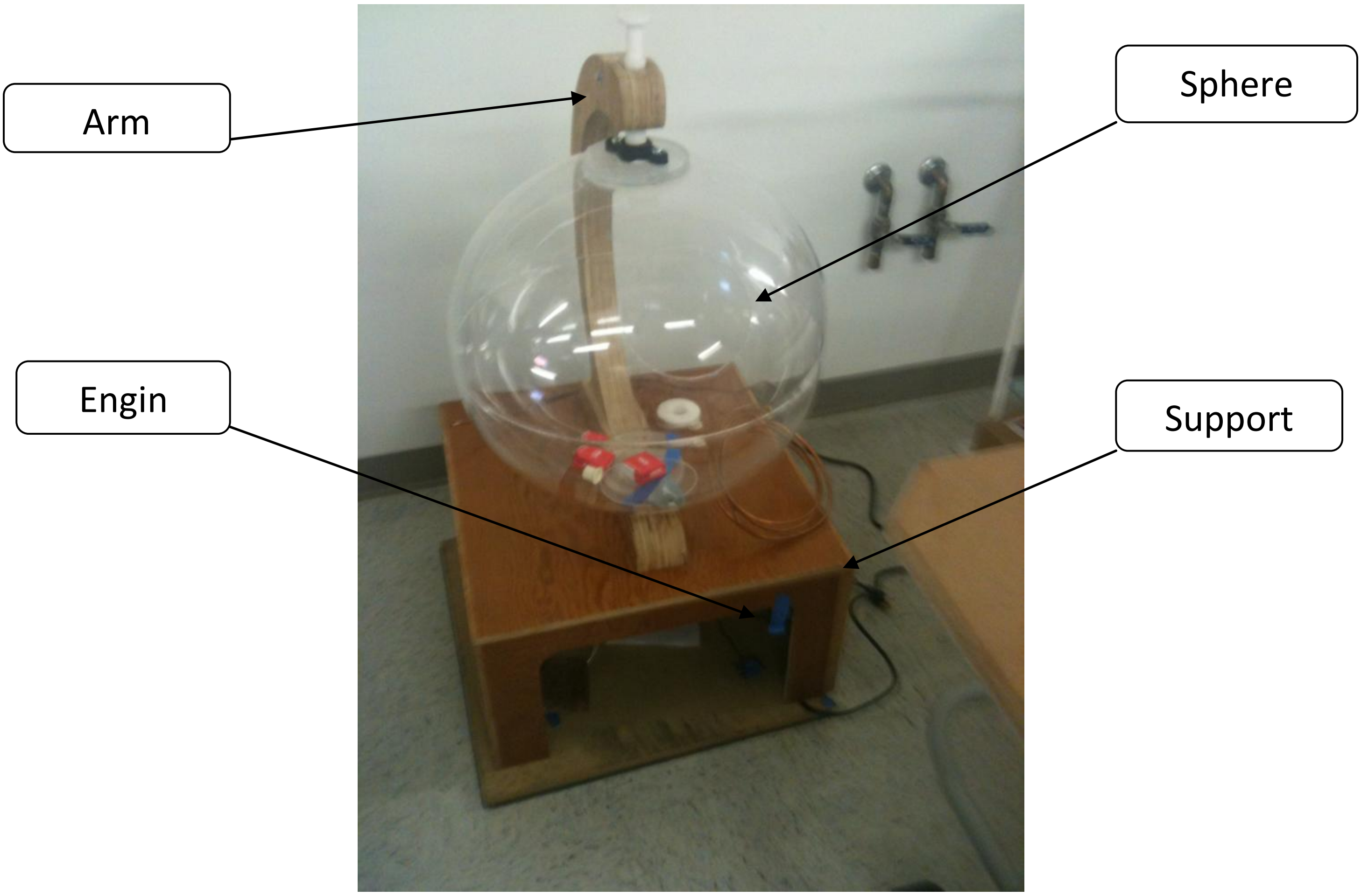
To visualize the fields, we want put a fixed antenna in the sphere emitted at 900 MHz. Our second goal was to make a lot of electronic cards around who received the signal and change the LED's color with the power received. The sphere is driven by a motor and rotates around a fix axe.

What is the RED project? And why work on this project?

The RED project was begun in the first semester of 2010 by three students for displaying an electromagnetic field of the cell phone bandwidth making it visible to the naked eye. The following is a summary written by the students.

> ***"The RED (Real-Time Electromagnetic Field Display) project has an overall goal of displaying an electromagnetic field of the cell phone bandwidth in the visible spectrum in order to help provide a better understanding of the creation of EMI by wireless equipment. In order to do this, the RED displays the intensity of an enclosed electromagnetic field by representing field strength as a color from blue to red. As the display sweeps around the field the varying intensities at different places around the source is represented in real-time. The overall effect is to model the field strength in 3D.***
>
> ***Our circuit consisted of five basic stages: an antenna & buffer, two amplifier stages, a log-detector stage, and a processing/display stage. In development, we used a small wire for our antenna. The antenna buffer uses a MESFET that offers a high input impedance and source power to the next stages. The amplifiers are 20dB amplifiers designed for RF analog signals. The log detector converts the signal power on a decibel scale to a DC voltage representing the power level. This DC signal is then input to the microcontroller ACD. Depending on the input voltage, the three colors of the RGB LED are varied using pulse-width modulation, resulting in an array of colors.***
>
> ***Although we did not build the actual mechanics for displaying the electromagnetic field in three dimensions we did specify the design. In its most basic form the mechanics consist of a clear acrylic sphere on which to mount the circuits, a frame to hold it steady, and a motor to spin the sphere around 600 rpm. "***

The goal of this project was to find a simple solution to visualize the field emitted by an antenna. We have visualized this field on an RGB LED. This one varied when the power of the field changes. The microcontroller analyzed the signal received after the both Amplifiers of 20dBm and the log detector and it changes the color of RGB LED in function of the received signal.



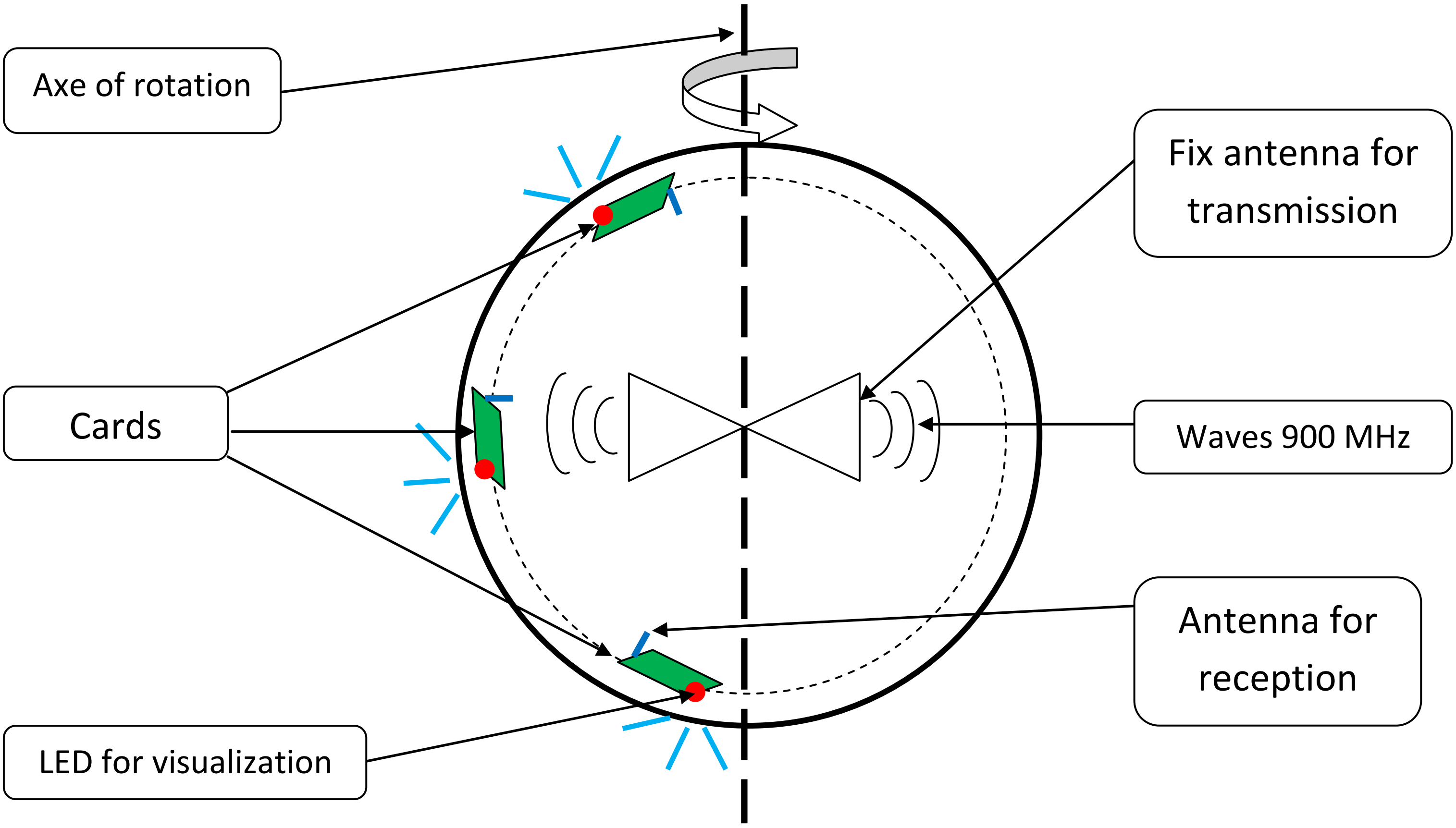
You can see in this picture the sphere when we are arrived in June

Work to be done during our internship:

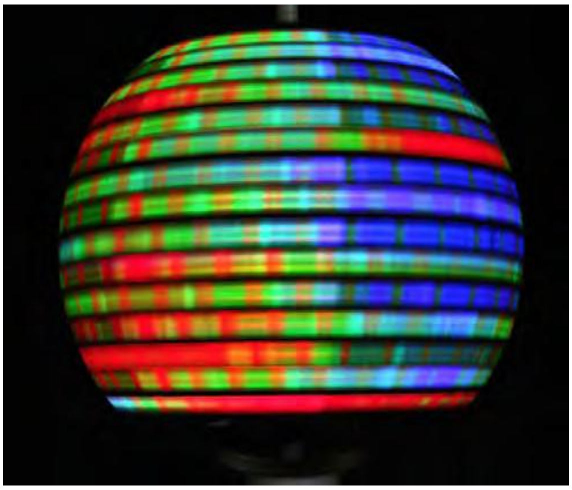
The Project was not finished when we arrived in the Lab. We had to do a lot of modifications and conceptions.

- Electronics cards was not functional,
  - Problem with the first stage, the soldering and card's antenna.
- Problems of frictions and shaking when the sphere rotate,
- Protection around the sphere,
- Conception and fabrication of a fixed antenna inside the sphere,
- Conception of a system for an outside alimentation for cards inside the sphere,
- Work on the software to program the microcontroller,
- Test all cards and debug them, if it is necessary.

2. Sphere's principle



Sphere's principle



When the sphere rotates, you can view the field. Cards are placed around and inside the sphere.

We use ten cards around the sphere. Like that is easier to visualize the field emit by the antenna when it turns.

The principal antenna emits at 900MHz. We have chosen this frequency because it is the cellular frequency. In the future we could make a real cellular phone inside the sphere and visualize its fields. When we use a cell phone near the sphere, you can see peaks emitted by the cell phone.

3. Cards' principle

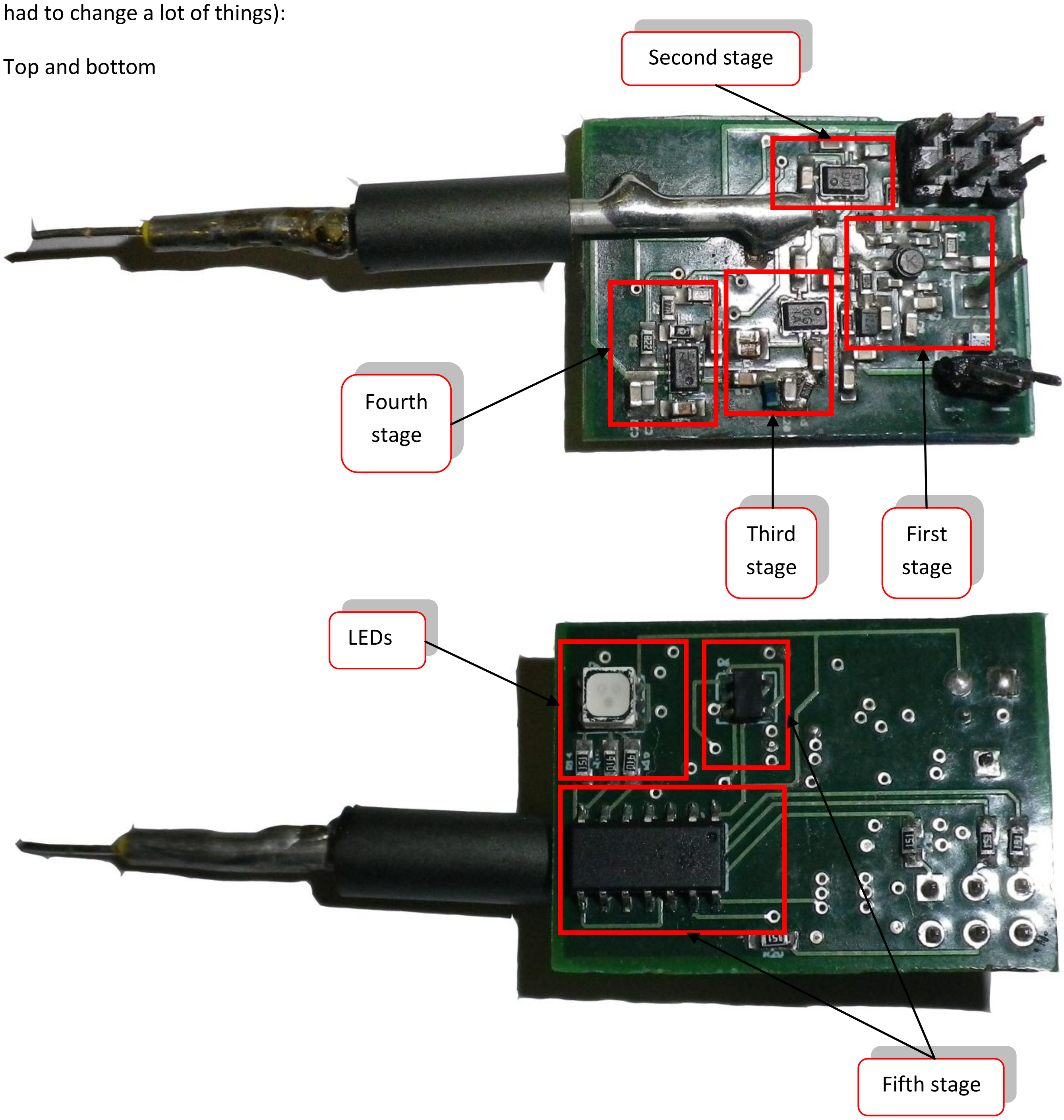
The cards were the most difficult part of this project. We would like every card to be the same. It was very difficult to find an answer for all of the cards.

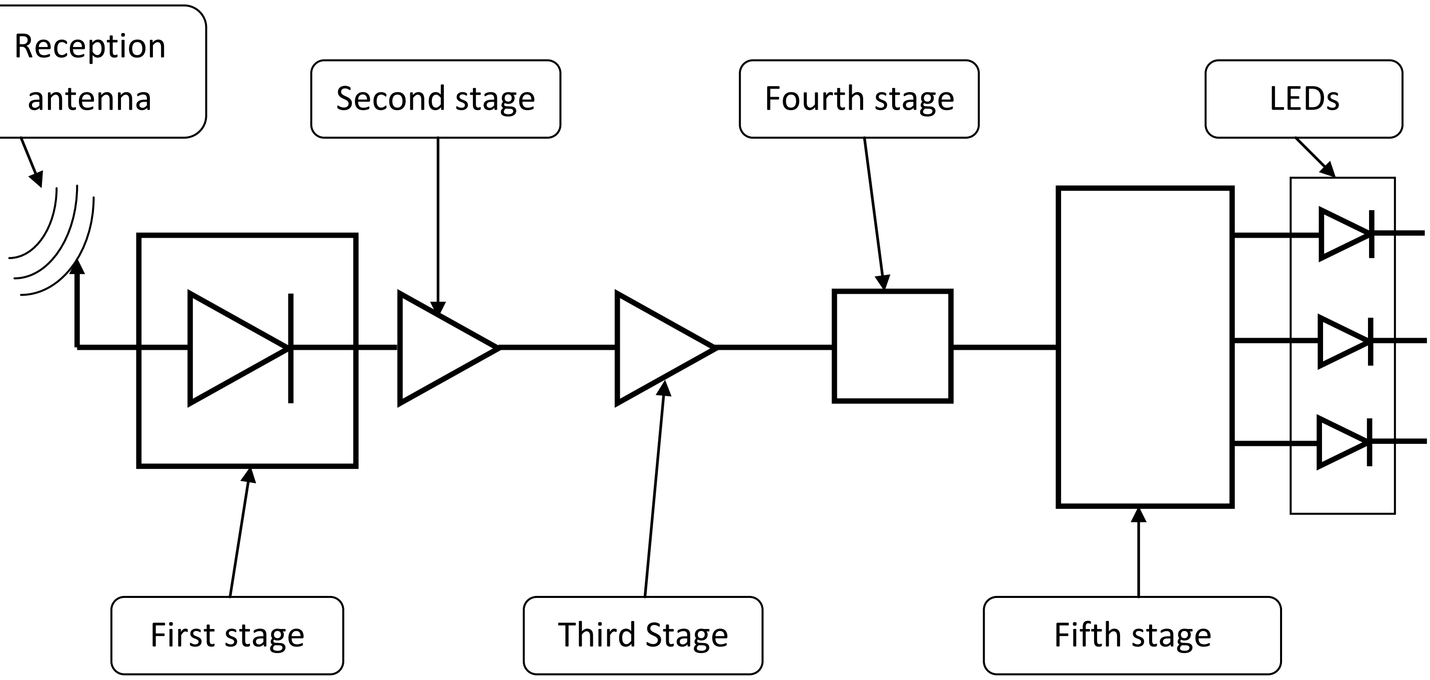
You can see, in **annex 2, 3 and 4**, respectively the PCB prints, the schematics prints of Altium and the bill of materials that the card used.

When we are arrived in the lab, Dr. Pommerenke tells us about this project. It was started by other students a couple months before. And it was a real pleasure to continue this one.

With this picture, you can just see a basic card finished (because after working for a long time, we had to change a lot of things):

Top and bottom





You could see on this schema the fourth stages and the microcontroller used for the tree LED

The antenna on the card receives a signal emitted by the fixed antenna inside the sphere. This signal is a 900MHz signal like for the cell phone (in the future, we could use a cell phone instead of the fix antenna to visualize field emitted by this one). This signal is amplified and analyzed by a microcontroller. The microcontroller controls the DEL's color. If the power of field received is high, LEDs will be Red, if it is weak, LEDs will be Blue light.

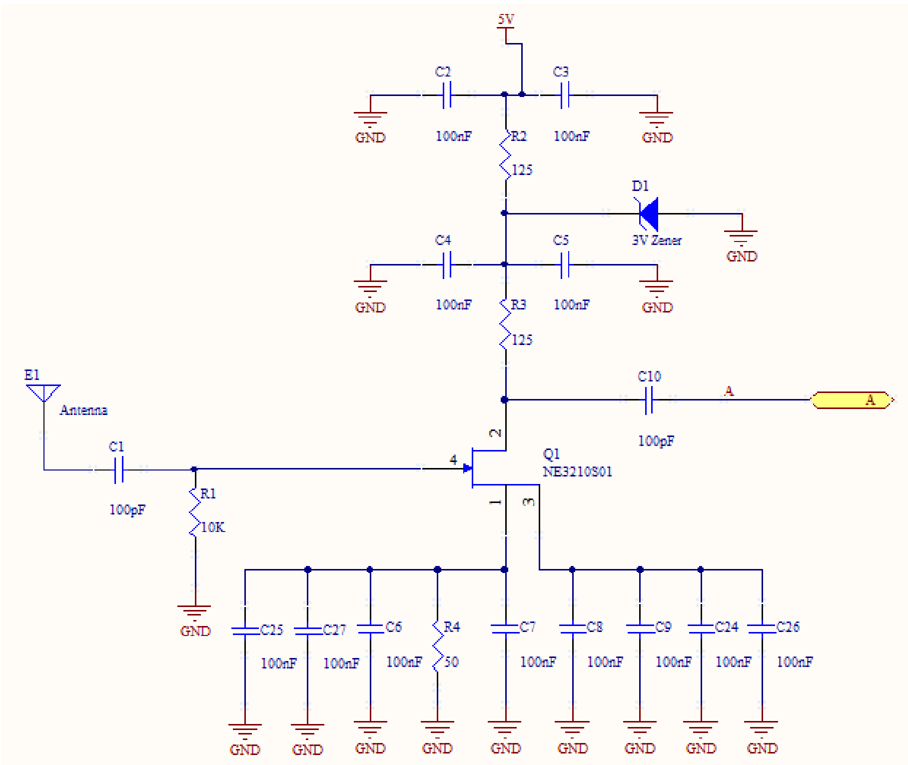
Here you could see the different LEDs' colors according the power of the field received:

Gain (dBm)	**RF off**	**-10**	**0**	**7**	**17**
LEDs' color	**Blue Light**	**Green**	**Yellow**	**Orange**	**Red**

- **<u>The first stage:</u>**

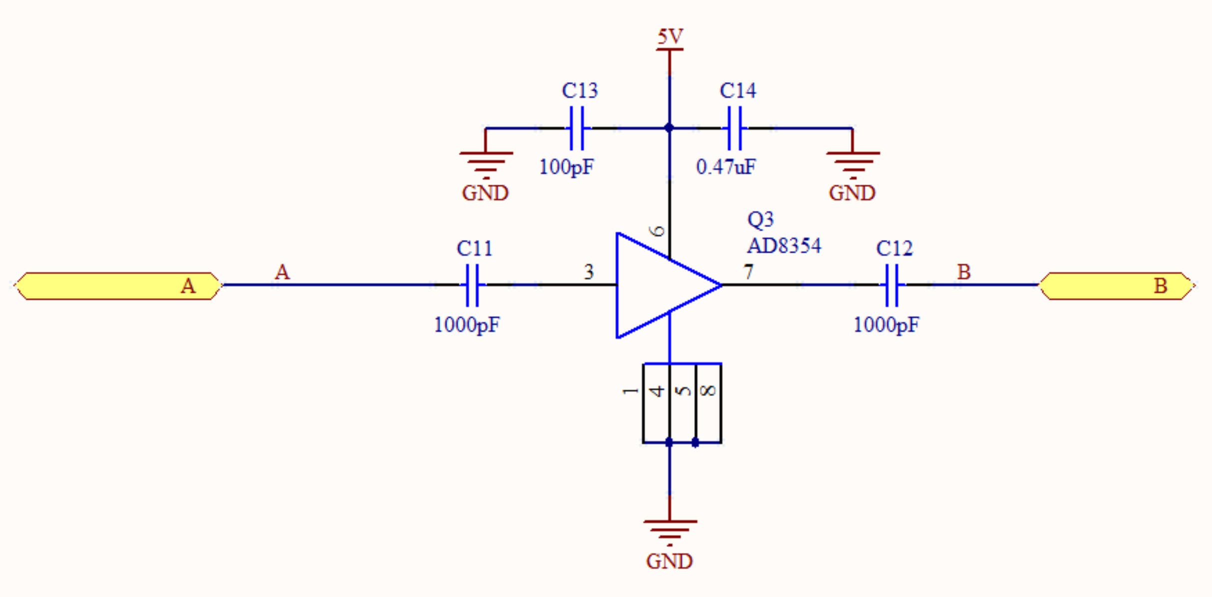
The signal is received by an antenna and analyzed by the **first stage**. This stage is an Antenna Buffer. This stage receives the antenna's signal and is an acquisition of the received signal. When we arrived the schematic was with this stage, but in fact, when we have worked on this, we have found a lot of problem with this. It was very difficult to balance cards with this stage. The cards' color was all different when they were received in the same field. We have worked on this part for a long time. We also changed the antenna three times. Finally, we have removed this stage and placed the antenna just before the second stage. I will speak about antenna after explaining the electrical subsystem.

This first stage should be a buffer amplifier of about 10dBm gain at frequencies up to 12GHz. This was chosen due to the high frequencies used in the cellular phone.



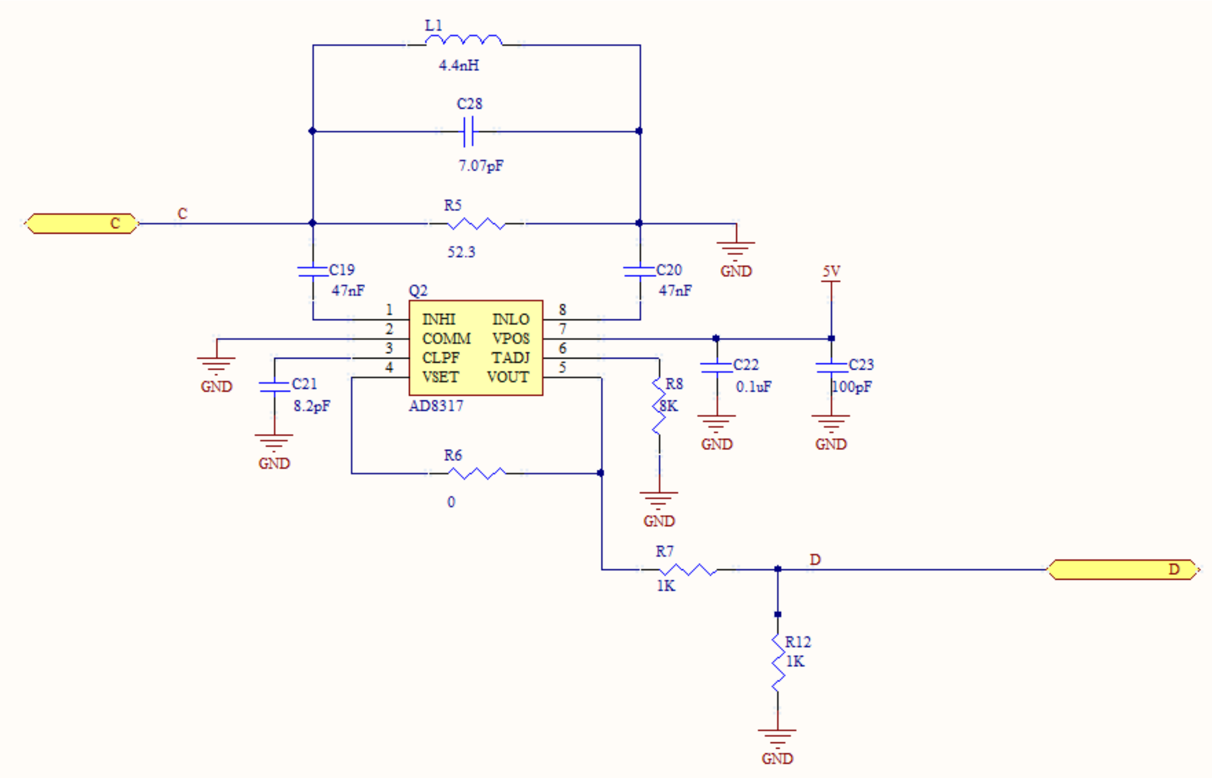
- **The second and the third stage**

The second and the third stages are identical. They are the first and the second stages of amplification respectively. We have used an AD8354 RF 2.7GHz gain block to increase the gain 20dBm in each stage. With these two stages, we have an amplification total of 40dBm. It is important for the next stage to have a good amplification of the signal emitted by the antenna. Otherwise, the signal received is too weak for the log detector's stage.



- **The fourth stage:**

This stage is a log-detection stage. This stage convert the RF input from the amplification stages to amplitudes readings on a decibel scale represented as a DC value. This DC value is in the range of 0.35V for a signal of around 17dB input power, to 1.75V for a signal of around -60dB. The output range of the log-detector is not ideal given the voltage reference of the analog to digital converter (ADC) provided by the microcontroller in the next stage, therefore it is level-shifted using a simple voltage-divider circuit to a range of 0.2V to 1.1V DC. Depending on this output the need of the amplification stages can be determined. Since ambient signals ultimately affect the reading, as they are picked up by the antenna, a simple band-pass filter was added to the input of the log detector. For our experiment, this filter is tuned to 900 MHz to sense only EMI in the cellular phone band, but the values of the inductance and capacitance can be altered to accept other frequencies, such as the 2.4 GHz band.



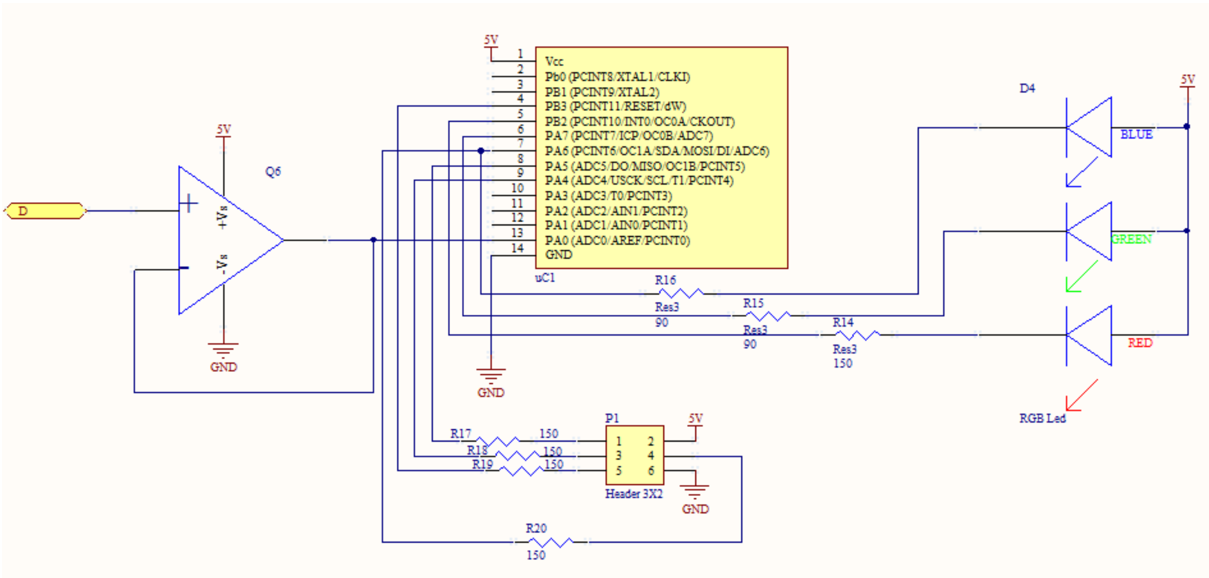
- **Fifth stage:**

The fifth and the last stage is the stage of the microcontroller. An 8-bit ATTINY84 microcontroller from Atmel is used as the main display processing element. This stage receives the signal of the log detector and then maps it to a color for the RGB leds.

We used an op-amp because the input impedance of the fourth stage is rather low.

The input from the log-detection stage is buffered and converted to hex range and output as a color on the LEDs. Blue represents low field- strength, and red represents high field-strength.

As mentioned above, by using a voltage-divider network the voltage range is easily shifted such that the internal 1.1V voltage reference can be used and an external reference wasn't necessary. Given a range of 0.2V to 1.1V the ADC converts this to a hex value from 0x2D to 0xFF. The microcontroller subtracts this value from 0xFF (since a higher voltage corresponds to lower signal strength) and then maps this value to one of the 256 colors. These colors are then sent to the LEDs via three PWM channels (one for each color LED in the package



Arnaud Royer had worked on the code. The code used is displaying in a CD attached to the report.

4. Cards' antenna

In order to receive the field emitted by a fix antenna inside the sphere, we need an antenna on our cards. That was a very difficult point in this project; finding an antenna that works similar for every card.

The first part of our work in the lab was to soldier ten cards. It was the first time for us to soldier CMS 0.3. We spent a lot of time at this work.

We have learnt to use a hit gun to soldier CMOS components.

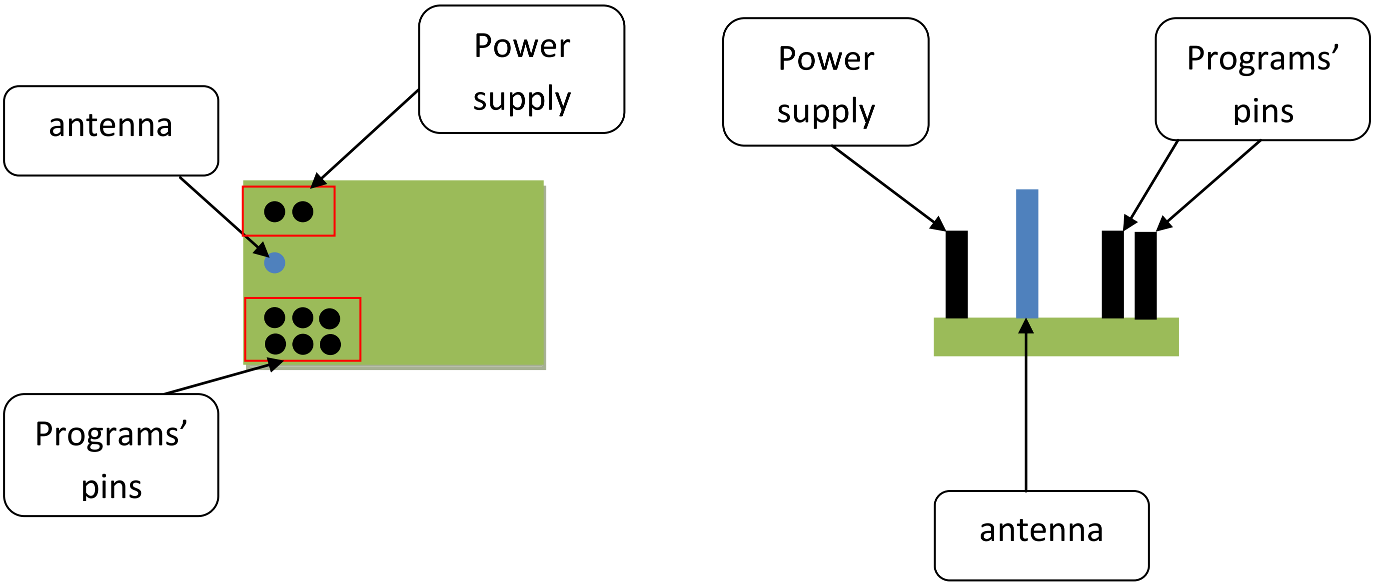
On this picture, you have all the material used to soldier. You can see the hit gun, a microscope with it light, a computer (to see on the PCB print witch component used) and special tape.

Hit gun is used to soldier with precision components. Hot air is ejected (370°C) and it is easier to soldier with this one.

It is very interesting to learn soldering, but so complicated in the beginning. Components are small, and in our first cards, we had a lot of problems with soldering. I made a lot of mistakes with components CMS. The main error is due to the ground.

- **First antenna**

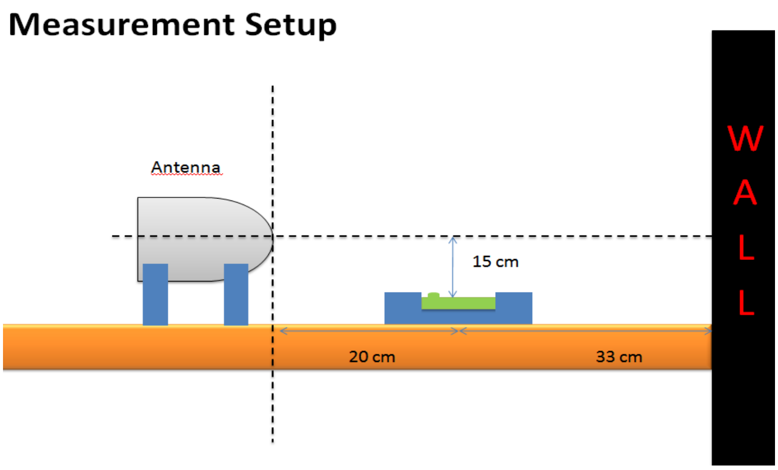
Primarily, we used the antenna proposed by the other students who worked on the project before us. This antenna is a small antenna of 2 cm fixed before the first stage like in this schematic.



Two points of view of a card with the first antenna.

We had a lot of problems with this one, because when the field was received, all the cards did not react the same way. The LEDs' color was very different, and never the same. To explain this phenomenon, and for each antenna, we have made a table with all the cards.

For this experiment, we have used a signal Generator Agilent N5181A. The frequency was 900MHz and we had used an antenna like in this schema in a vertical polarization.



The results are in this table. All cards are different and at this moment, the software was not finished. This is why you see a loop in colors.

	Card 1	Card 2	Card 3	Card 4	Card 5	Card 6	Card 7
RF Off	Oscillation Blue-Pink	Dark Blue	Dark Blue	Light Blue	Light Blue	Bright Red	Blue
-20 dB	dark blue	Dark Blue		Light Green			
-15 dB		Bright Blue					
-12 dB		Turquoise		Green			
-10 dB	light-blue	Ligth-green					
-7dB		Green					
-5 dB	Turquoise			Orange-Green			
-3 dB	Green	Orange					
0 dB	Green Yellow	Orange-Red					
3 dB	Orange		Light Blue				
5 dB	Orange-Red	Red					Light Blue
6,6 dB		Oscillation Blue Pink					
9 dB			Turquoise	Orange			
10 dB	Bright Red	Dark Blue					
11 dB	Oscillation Blue-Pink						
12 dB							Turquoise
13 dB	Dark Blue		Green	Dark Orange		Oscillation Blue Pink	
15 dB							Green
17 dB	Light Blue	Light Blue	Orange	Red	Green	Bleu	Yellow Orange

After speaking with Dr. Pommerenke about our problem, we found another solution. We have tried to remove completely the first stage and to introduce directly the generator signal before the second stage.

This manipulation was very important. At the beginning, we have seen that they are a lot of cards with problems of CMS solder or with components burned.

This manipulation was very important. Primarily, we have seen that they are a lot of cards with problems of CMS solder or with components burned.

After this test we wanted to know if the first stage was really important.

We have tested all cards without the first stage. The signal coming from the Agilent is going directly with a cable on the Q3 amplificator.

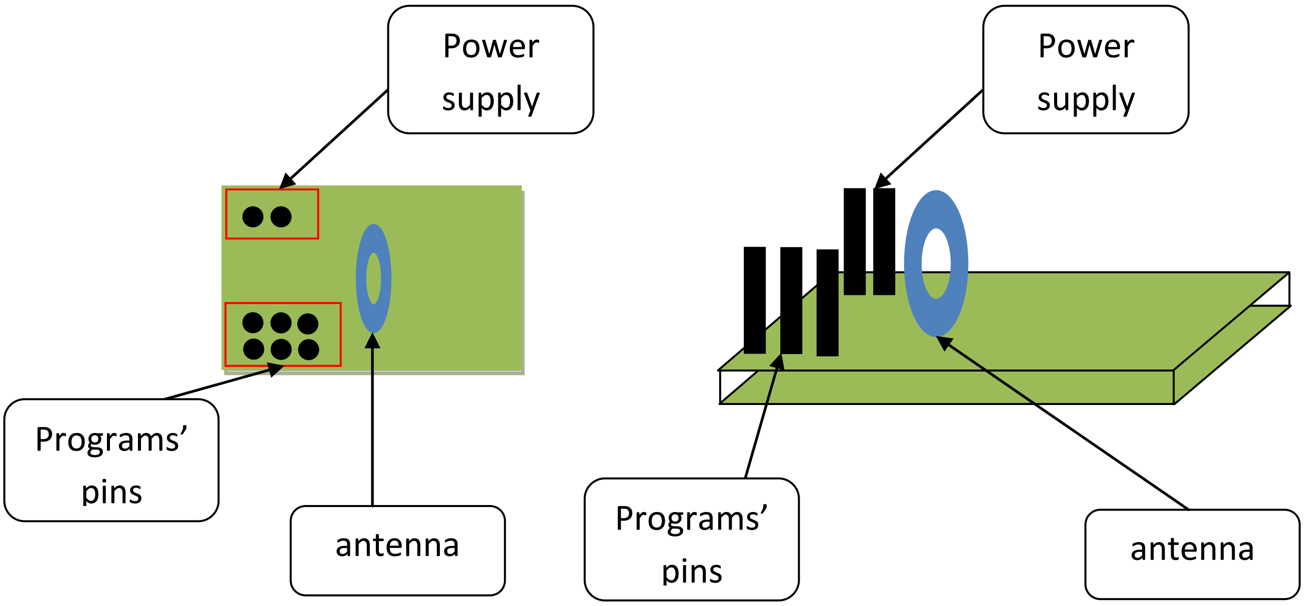
The results obtain without the first stage was very satisfactory. **This test is only to show the color variation according to the gain. It is why the scale is not linear.**

After this test, we decided to delete the first stage.

- **Second antenna**

In a second trial, we have tried with an antenna loop. This one was placed directly after the first stage. After testing this first stage, we realized than we had a lot of problems with this first stage and if the antenna is important enough (5 centimeters), it is not necessary to conserve it.

We have placed this second antenna like that:



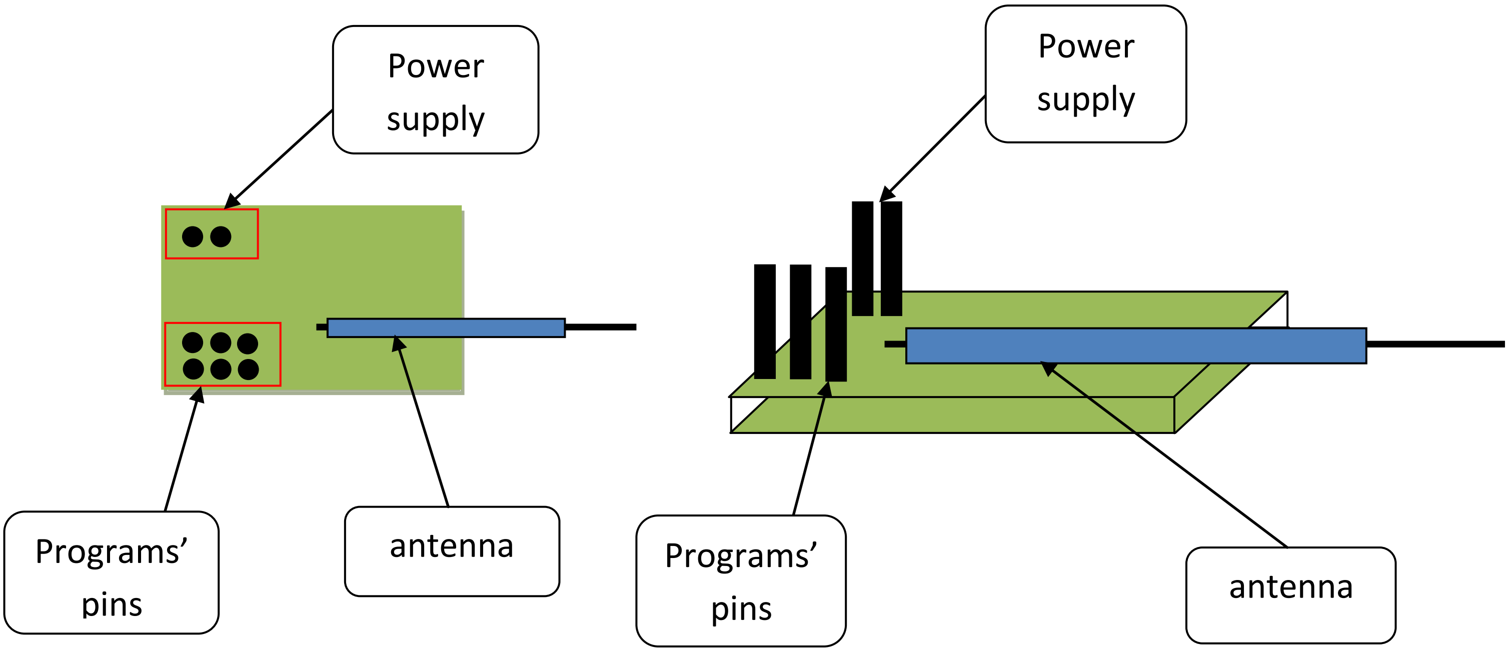
Two points of view of a card with the second antenna.

This antenna was satisfactory, but we have seen some incertitude. It is why we have decided to find another antenna that is more stable.

We have found our third and last antenna used in this project.

- **Third antenna**

Our last idea of antenna was like this schema. Like with the second antenna, this one was placed directly after the first stage on the Q3 amplificator.



Two points of view of a card with the third antenna.

This antenna was great for our experiment. It is an antenna with semi-rigid antenna coax cable with ferrite. It was stable and the results were great. The results are explained in this table:

	LED TEST	Programming
Card 15	ok	ok
Card 17	ok	ok
Card 20	ok	ok
Card 21	?	short
Card 22	ok	ok
Card 23	ok	ok
Card 24	red & green ok, blue failed	ok
Card 25	ok	ok
Card 26	ok	ok
Card 27	ok	ok

	PB	Reason
Card 15	sensibility issue	amplifier dead
Card 17	always red	
Card 20	always blue	
Card 21		
Card 22	big sensibility issue	2 amplifiers dead and maybe the log detector
Card 23	sensibility issue	1 amplifier dead
Card 24		checking LED connection or IC
Card 25	always yellow	
Card 26	sensibility issue	1 amplifier dead
Card 27	always red	

Finally, after all these tests, we have found a great antenna for our cards. We have put ten cards around the sphere.

Finding a great antenna and debugging ten cards took a lot of time. It was the most interesting part of this project.

5. External antenna

We had to create an antenna to emit the main signal. This antenna is a fix antenna inside the sphere. Here you can see its characteristics:

f = 900 MHz

c = λ x f	**<u>with</u>**	**c = waves celerity = 3.10^{8} m/s**
		λ = wavelength
		f = frequency

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3.10^8}{900.10^6}$$

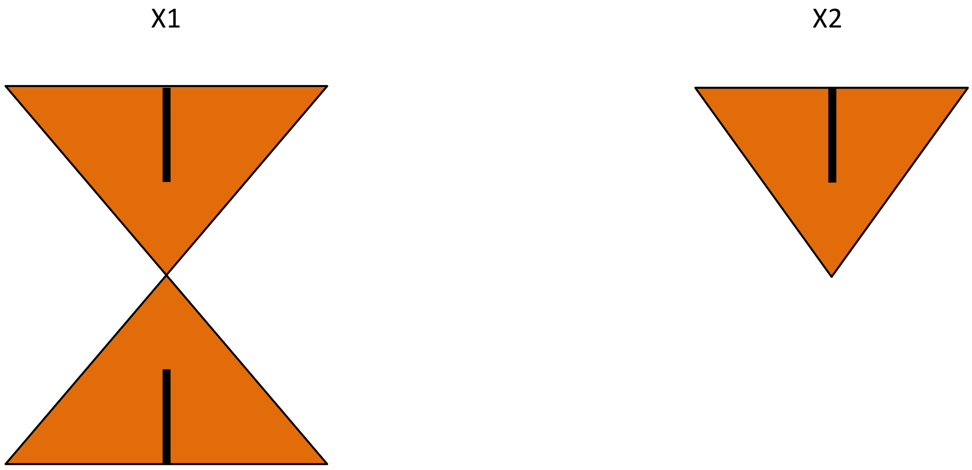
$$\lambda = \frac{1}{3}$$

$$\boxed{\lambda = 33\ cm}$$

We want an antenna to emit at 900MHz. We decided to used a size of $\lambda/_4$.

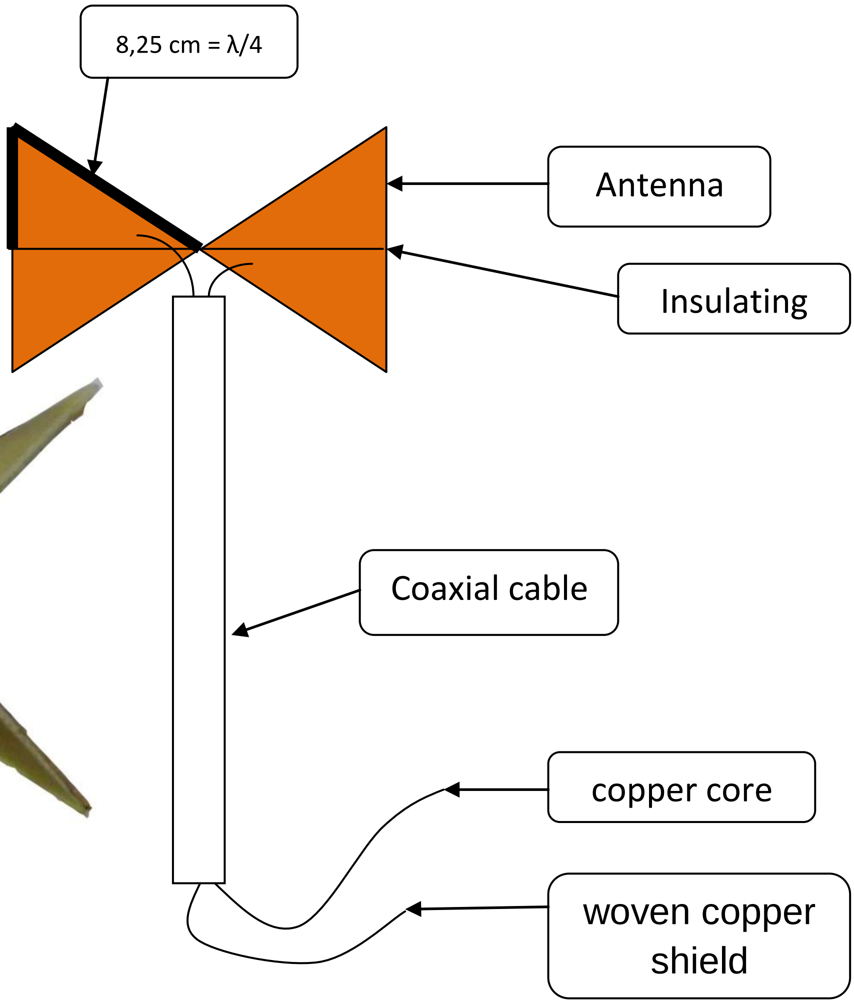
$$\lambda/_4 = 8{,}25\ cm$$

Our first impression was opted for a conic antenna. We have worked with a virgin PCB and used this one to confection our antenna. We have cut in the PCB one piece like that and two other similar pieces.



After this confection in the PCB, we just need to assemble the three pieces. This antenna is not conductive everywhere. We have used Copper tape on two edges. One conductive edge is fixed on the woven copper shield and the other on the copper core.

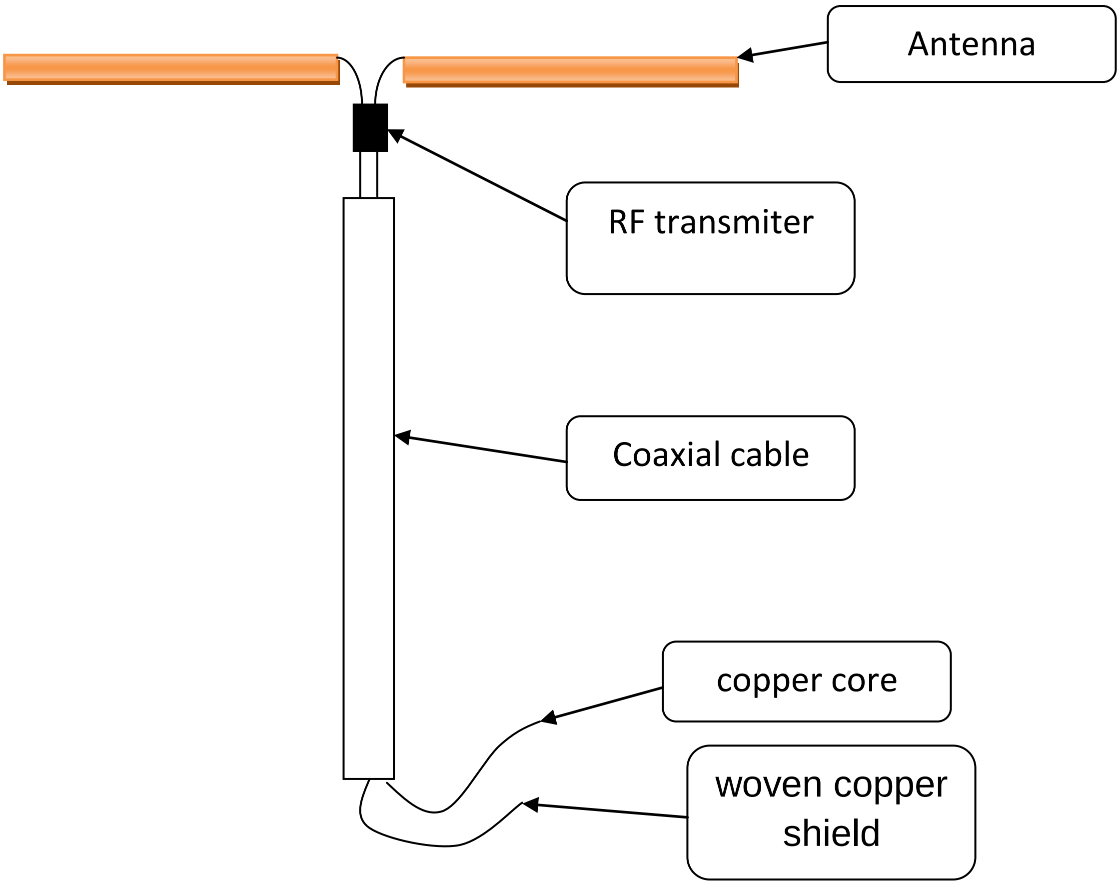
The final result was:



Secondly, we worked with another antenna. This one was easier. We have used two pieces of iron connected to an RF Transmitter. We have found an RF Transmitter who work at 900 MHz.

The RF Transmitter is an inductive circuit with ferrite. It is here just to insulate the generator to the antenna to stop the disturbances.

The principle is like our first antenna. The only difference is in the configuration of the two conductive parts.



There are a lot of differences between both of these antennas, we have visualized two different fields. The propagation is not the same in function of the antenna.

When all the cards worked, we have tried to visualize the field emitted by a cell phone. With the cell phone, we have observed impulsions emitted by the cell phone during the transfer of information. It was very interesting to see in 3D the field emitted by an antenna and a cell phone.

6. Mechanical works

a) Friction problems

When we arrived, the sphere was not finished.

The sphere arrived in the lab about two weeks after we arrived in the laboratory. It had a lot of problems with friction. We have changed and modified both of the white pieces around the top and the bottom of the sphere. After we changed these two parts, problems of friction were resolved.

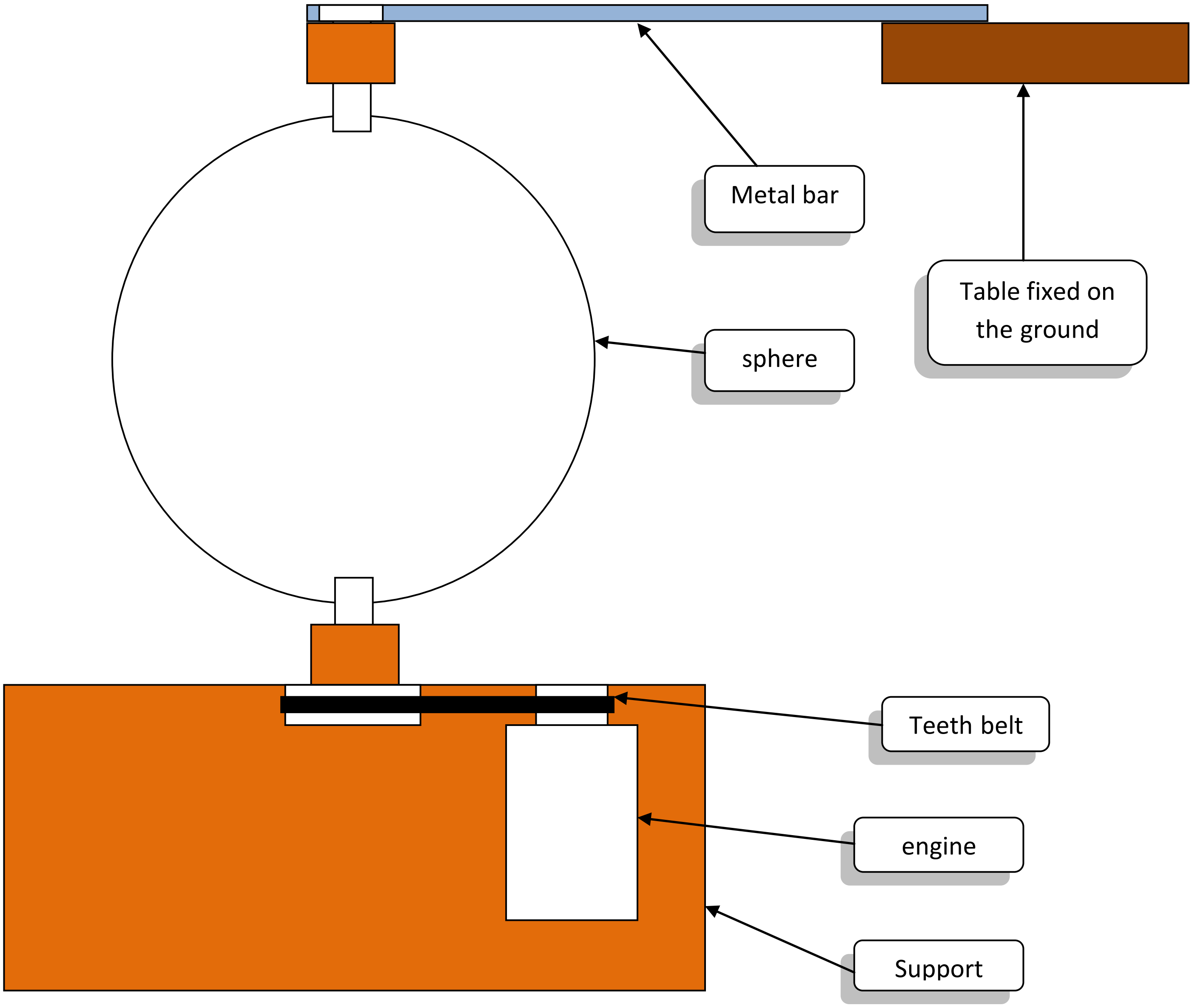
Moreover, the engine was used with a simple belt. After testing, we realized that this one was not enough. We have changed this by a teeth belt.

b) Vibration problems

Moreover, when the sphere rotated fast, we had a lot of vibration problems. It was so dangerous and difficult to work in these conditions. We worked to find a solution.

Our first idea was to fix the top of the sphere on something. We chose to fix them with a metal bar to a table fixed on the ground.

You can see here the fixation used for limit vibrations:



After this idea, the problem was almost resolved. But there were still some vibrations. It is why we have added weight to the support.

c) *Protection of the sphere*

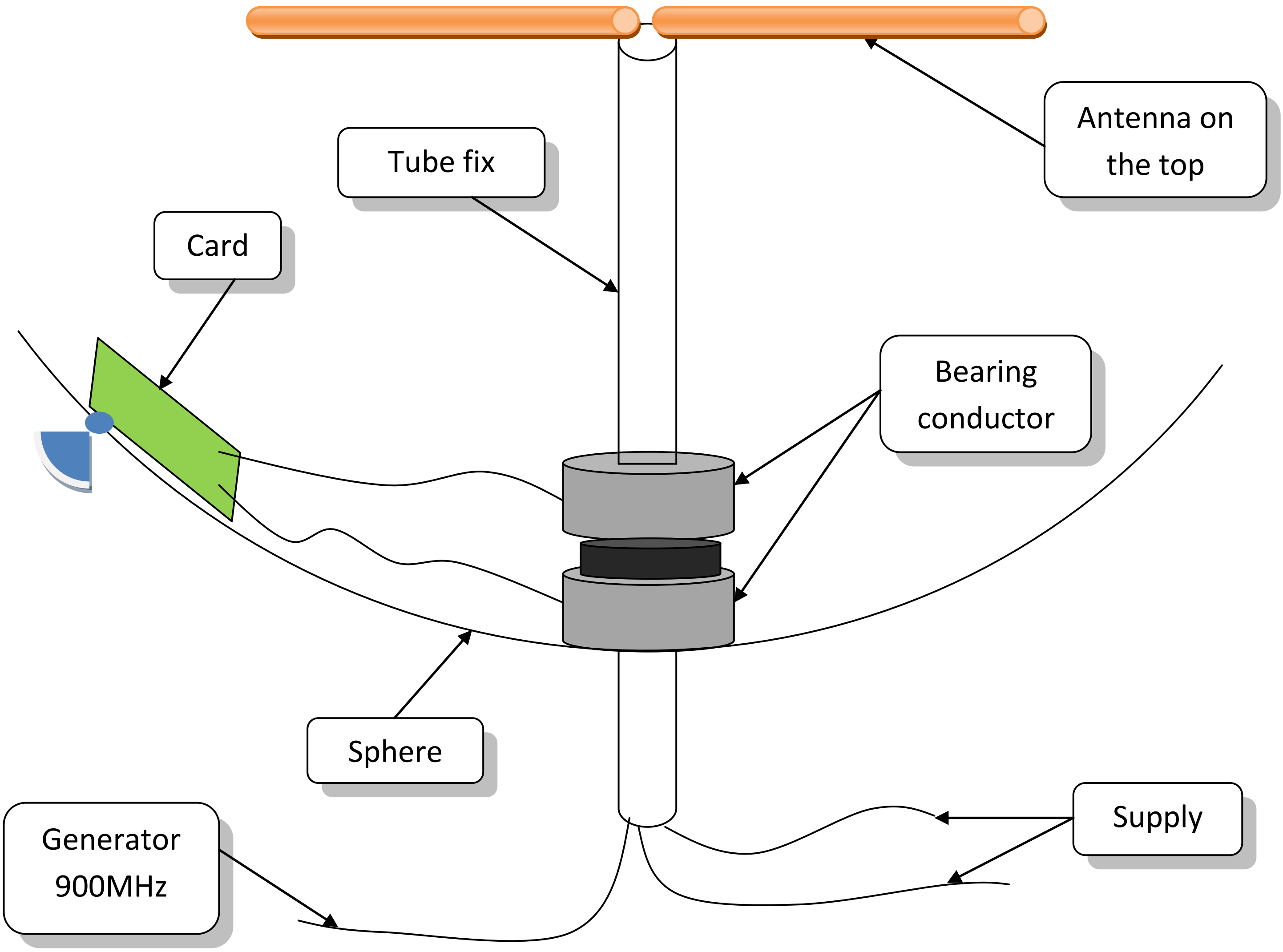
The goat of this project was to visualize the field emitted by an antenna. We set up this project to show to the students. It was very important that the sphere was secured. To secure the sphere, we have fixed protections around the sphere. These protections are attached directly in the support. The protection is in PVC around the sphere.

Moreover, the white piece on the top moved when the sphere rotated. We have fixed it on the support with a piece of metal.

d) *Support for the fix antenna in the sphere*

The most important part in our mechanical works was to find a solution to fix an antenna inside the sphere. We have used bearings because the antenna is fixed inside the sphere and cards turn with the sphere. We had to find a solution to supply our cards and balanced to prevent vibrations.

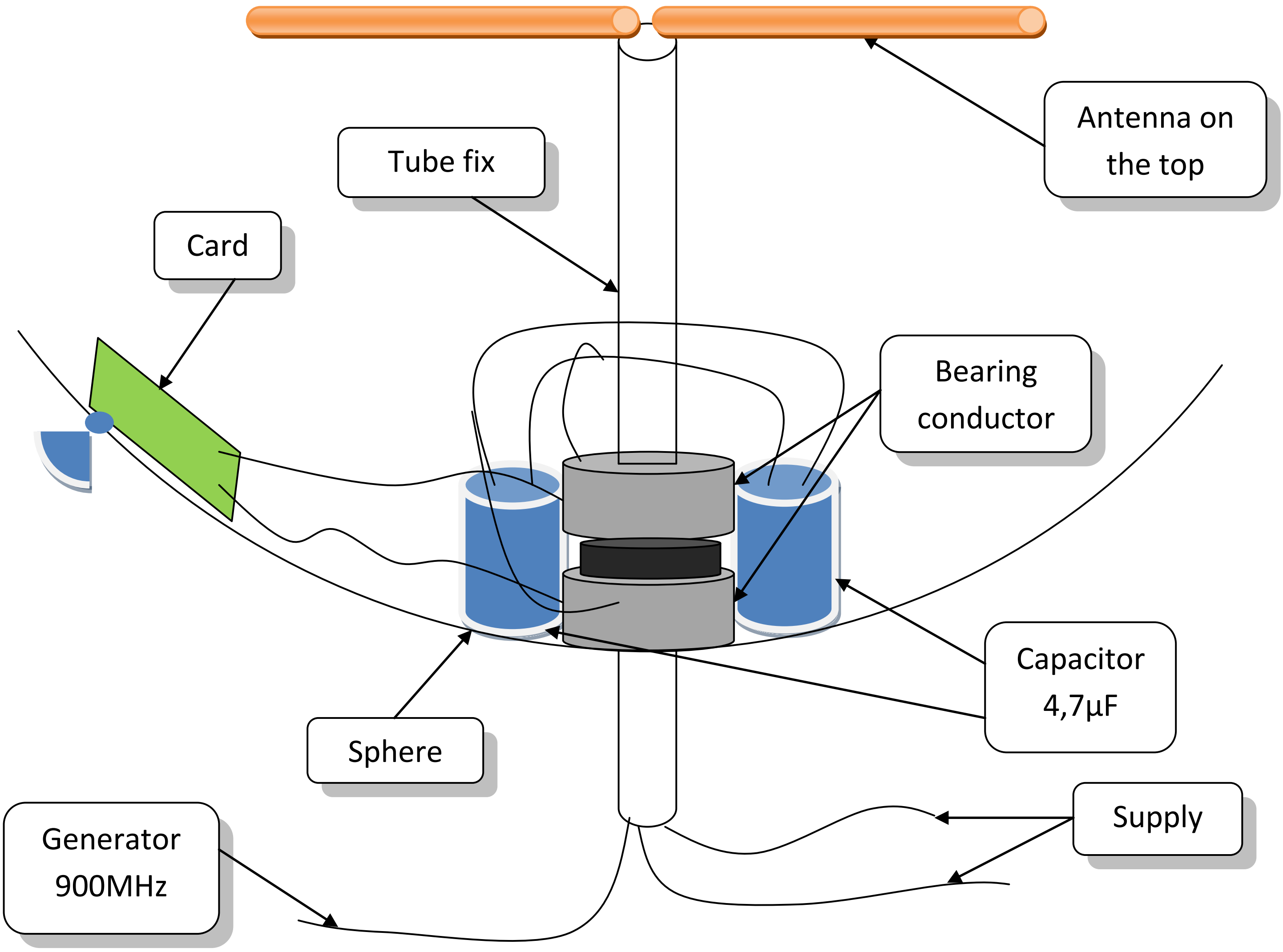
First of all, we have made installation like that:



The centers of bearings are fixed on the central tube and the other parts are fixed on the sphere.

We have tested this solution, and we have observed that there were problems of conduction on cards. The current was cut on and off when the sphere turned.

Our first solution was to place two capacitors in parallel to stock the current and stop the power cut.



Two capacitors in parallel added.

Interruptions were less important after adding the two capacitors, but they are still some interruptions. It is why we have decided to add a battery inside of the sphere.

The battery is in parallel with the supply, when the current of the power cut, the battery supplies the cards.

7. Conclusion

We have worked during three months on this project. It was our most important project of our internship. This project was really interesting because we have learned a lot of things about electronics. We have learned to solder, to debug, and to find solution for a lot of problems. It was very concrete and we have finished the project.

I have found this project very complete. In three months we had the time to think about a lot of solutions for our problems.

At the end of my internship, the sphere was running. We have tried to make a movie when the sphere was turning, but it was bad quality. I have included a CD of the video made of the sphere when it was finished and a lot of pictures about this project.

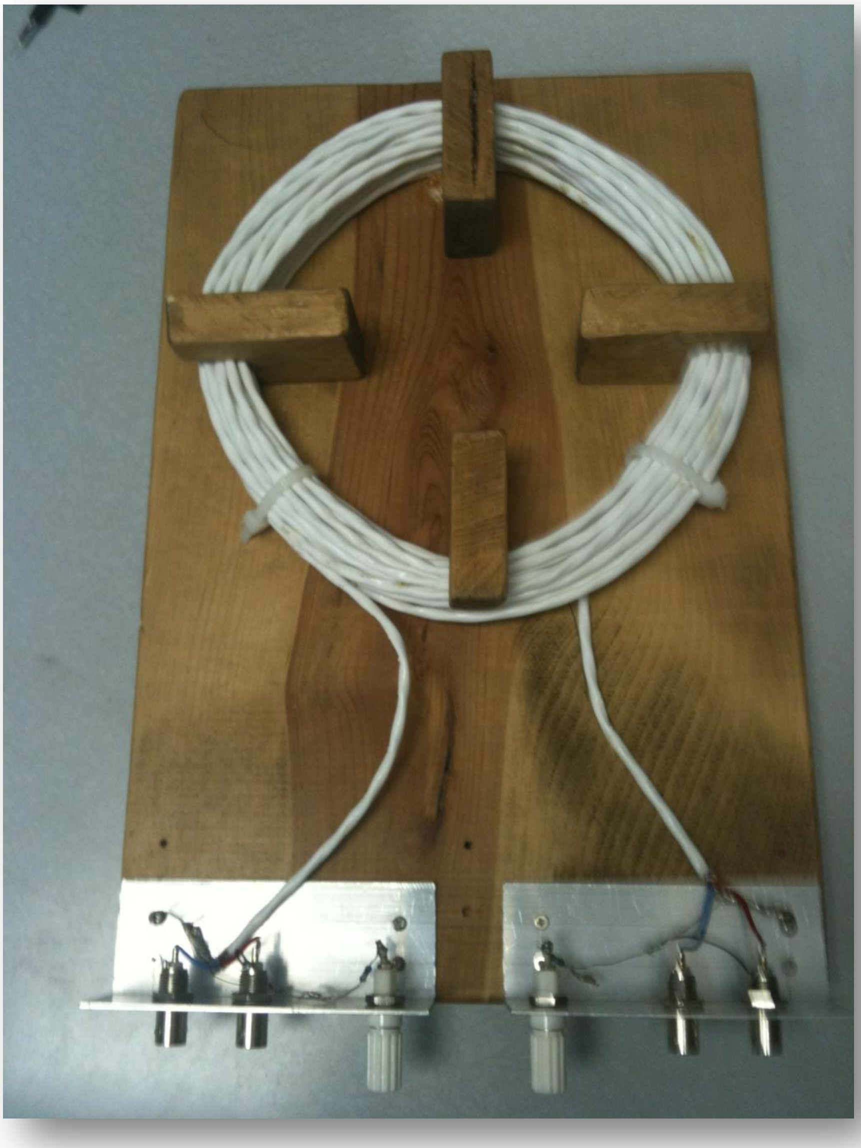
B. The Cross Talk project

1. Presentation of the project

We want to find the velocitie in the Twinax cable. After, we could use it for measuring characteristic impedances and the Cross Talk. The goal of this experiment was to measure Cross Talk.

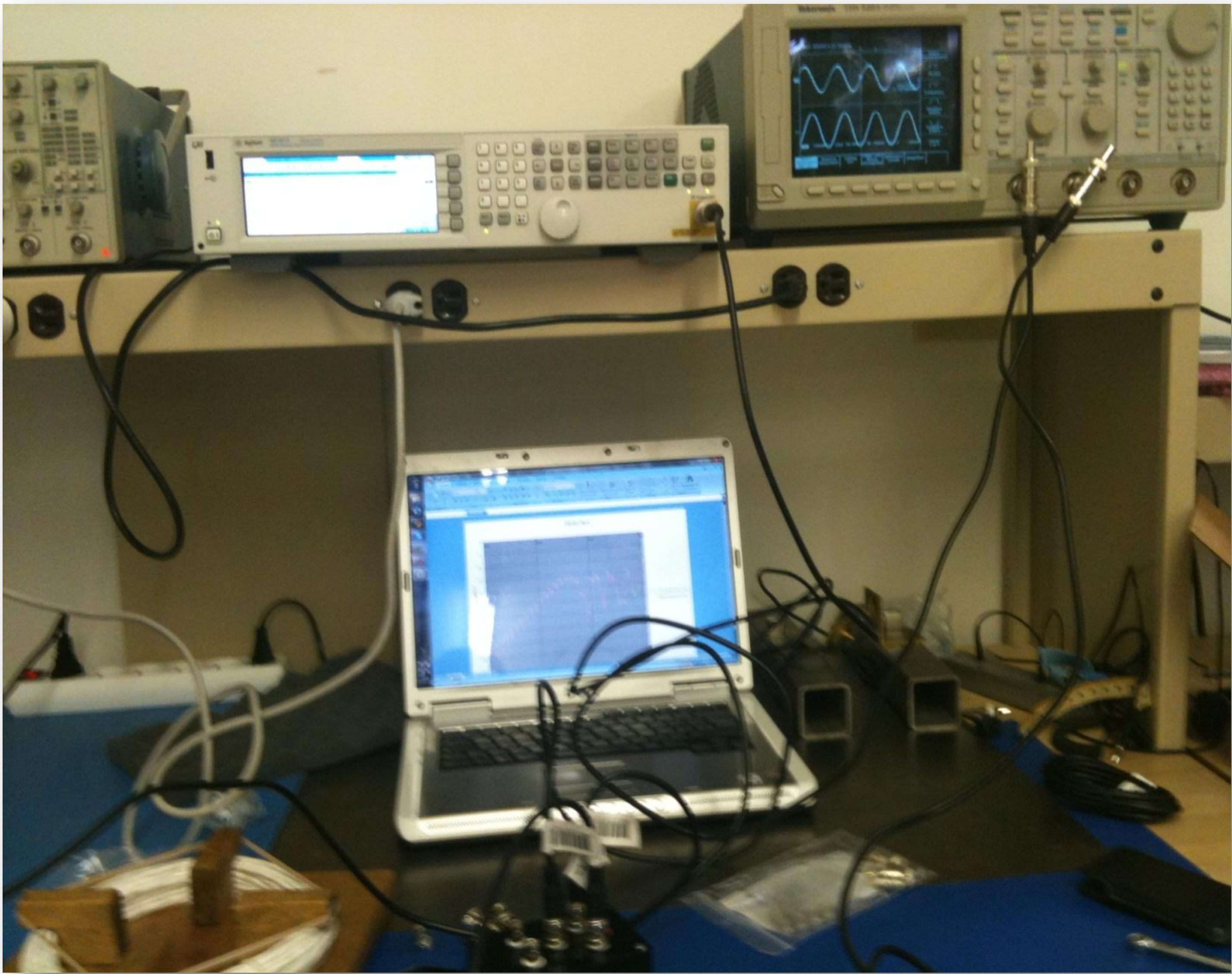
From www.wikipedia.com Cross Talk is:

> ***"In electronics, crosstalk (XT) is any phenomenon by which a signal transmitted on one circuit or channel of a system creates an undesired effect in another circuit or channel. Crosstalk is usually caused by undesired capacitive, inductive, or conductive from one circuit, part of a circuit, or channel, to another."***



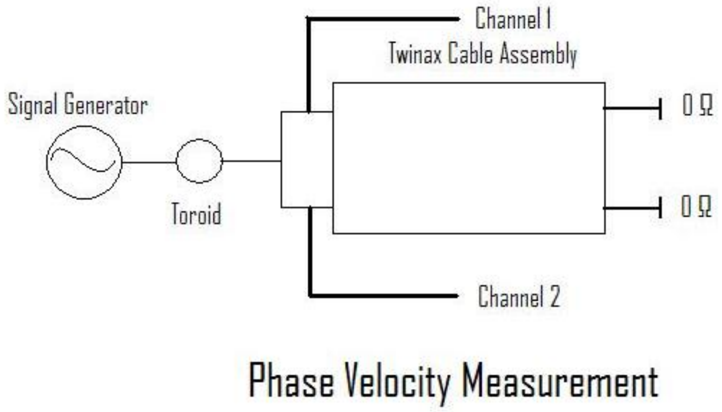
2. Equipment used

- Signal generator analogic Agilent N5181 with a bandwidth of 100kHz to 3GHz,
- Agilent infinitiium oscilloscope (1,5GHz - 8GSa/s),
- 6, BNC T-connectors,
- 2, 0 Ohm terminations,
- 8, 50 Ohm terminations,
- 1, Twinax cable assembly (15 meters),
- Laptop software/program with Excel.



3. Phase velocity measurement

Firstly you must measure the phase velocity. To measure this, we have used a simple schema. We want to find the propagation constant; it is why we put a short circuit at the end of the cable like in this schema:



To find the propagation constant, we want to find the frequency until the level of the channel 1 and the channel 2 is at a minimum.

There are two modes of measurement in this project. It is why we have to realize experiments in an Even and Odd mode.

Typical Pi termination for a coupled line pair

To terminate both the even and odd mode, we have a method. First, simply terminate the two lines with the correct even mode value of terminating resistor to ground (let's call these two resistors R_A and R_B), and then add an additional resistor R_C between the pair.

Even Mode:

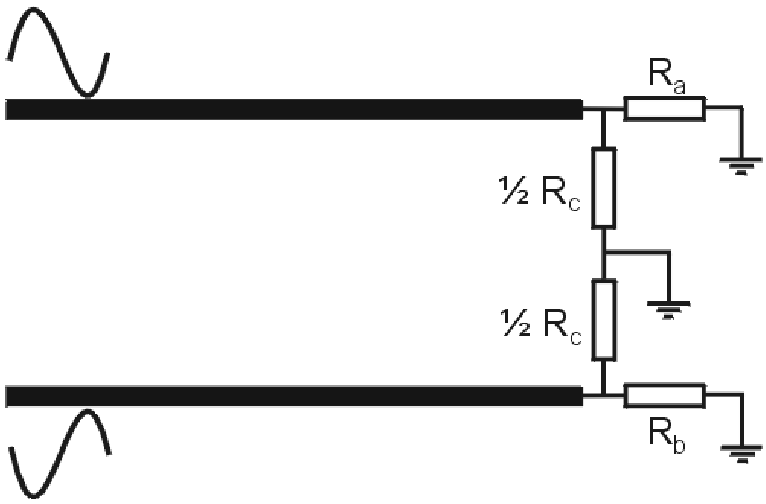
> ***"The impedance measured testing one of a pair of lines which are driven by identical signals (Even mode is twice the common mode value)"***

Equivalent termination in Even mode

In the even mode, the resistor is invisible if the signal on each track is identical. So there is no current flow in this resistor.

Odd Mode:

> ***"The impedance seen when testing the impedance of one side of a pair of lines when the other is drive in equal and opposite polarity (half the value of the differential impedance)"***



Equivalent termination in Odd mode

In the odd mode the centre of R_c will always be at 0v. Now it is an half of R_c will appear in parallel with the even mode terminating resistor. So the odd mode impedance is equal to ½ R_c in parallel with R_a.

Find the velocity:

We have 13 meters of cable.

$$\lambda = 2 \text{ x } 13 = 26 \text{ m}$$

$$\lambda = \frac{c}{f}$$

$$c = \lambda \text{ x } f$$

With the short circuit, and with the schema used on the start of this part, we can find the velocity.

We work at **7.6 MHz**

$$c = 7.6.10^{-6} \text{ x } 26$$

$$\boxed{c = 1.976.10^{-8} \text{ m.s}^{-1}}$$

Because wires are covered by arc electric => $\boxed{c < c_{freeair}}$

An expression between impedances and tensions:

$$\beta = \frac{2\,\pi}{\lambda}$$

We want to find Z_0 $Z_0 = ?$

- $\Gamma_L = \frac{Zl - Z0}{Zl + Z0} = \frac{V-}{V+}$

- $V^+ e^{\beta\, l} + V^- e^{-\beta\, l} = j\,(V^+ - V^-)$

So,

$$\frac{|V2|}{|V1|} = \frac{|\,j\,(V+ - V-)\,|}{V+ - V-} = \frac{|j||V+|(1 - \Gamma L)}{|V+|(1 + \Gamma L)}$$

$$\frac{1 - \Gamma L}{1 + \Gamma L} = \frac{1 - \frac{Zl - Z0}{Zl + Z0}}{1 + \frac{Zl - Z0}{Zl + Z0}} = \frac{ZO}{ZL}$$

$$\boxed{\frac{|V2|}{|V1|} = \frac{ZO}{ZL}}$$

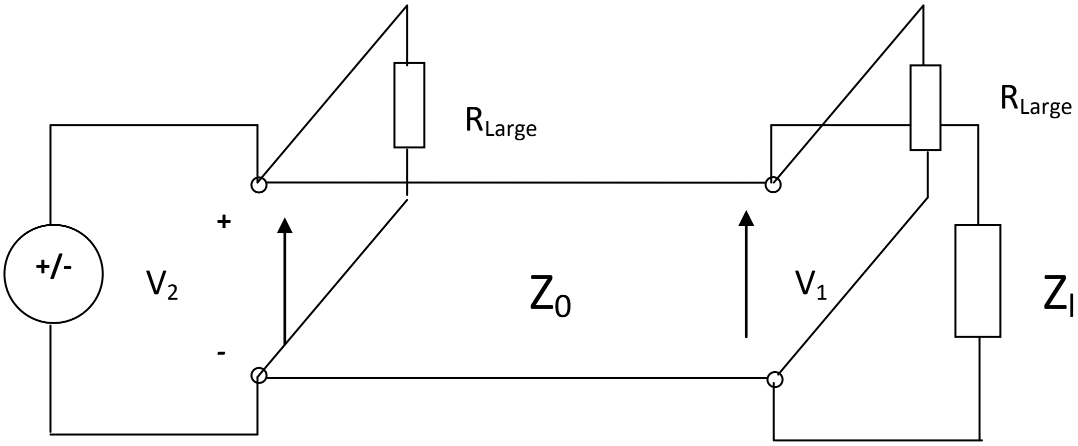
4. Characteristics' impedance measurement

We have made two characteristics' impedance measurement. One with 50 Ω in parallel directly on the oscilloscope, another with 25 Ω on the oscilloscope.

We know Z_L and we want to fine Z_0.

$$Z_0 = Z_L \times \frac{|V2|}{|V1|}$$

We use this schema to determinate characteristics' impedance:



R_{Large} is chosen in function of the price. Moreover, with 50Ω, we have observed than we have a better report on the result. Transmission, reflection and losses are in correlations.

We have made a lot of characteristics' impedance measurement at **3.8MHz.**

Even mode:

0 dBm	**->**	**50Ω**	**Z_e = 36,56Ω**
		25Ω	**Z_e = 33,48Ω**

Odd mode:

0 dBm	**->**	**50Ω**	**Z_0 = 26,71Ω**
		25Ω	**Z_0 = 26,55Ω**

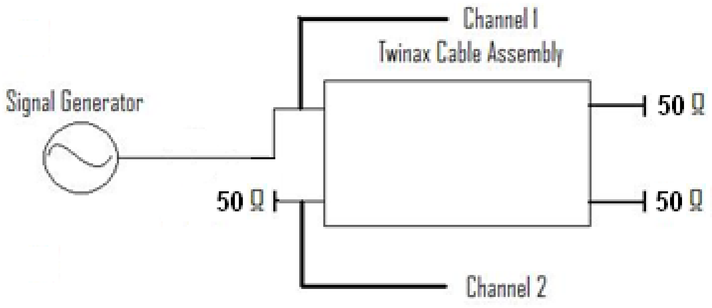
We increased the gain to improve the stability of results. We found a gain max without distortions. And ***G_{max} = 15 dBm.***

We have worked with a table on Microsoft Exel.

CROSS-TALKER				
MEASURED QUANTITIES				
PHASE VELOCITY FOR EVEN MODE	1,97E+08	METERS PER SECOND		
PHASE VELOCITY FOR ODD MODE	1,97E+08	METERS PER SECOND		
ODD MODE IMPEDANCE	26,55	OHMS	30,6	26
EVEN MODE IMPEDANCE	33,48	OHMS	41	36

5. Cross Talk measurement

Finally, we have made a measurement of the Cross Talk. To realize these measurements, we have made this schematic:



These measurements are presented in this following table for each frequency used:

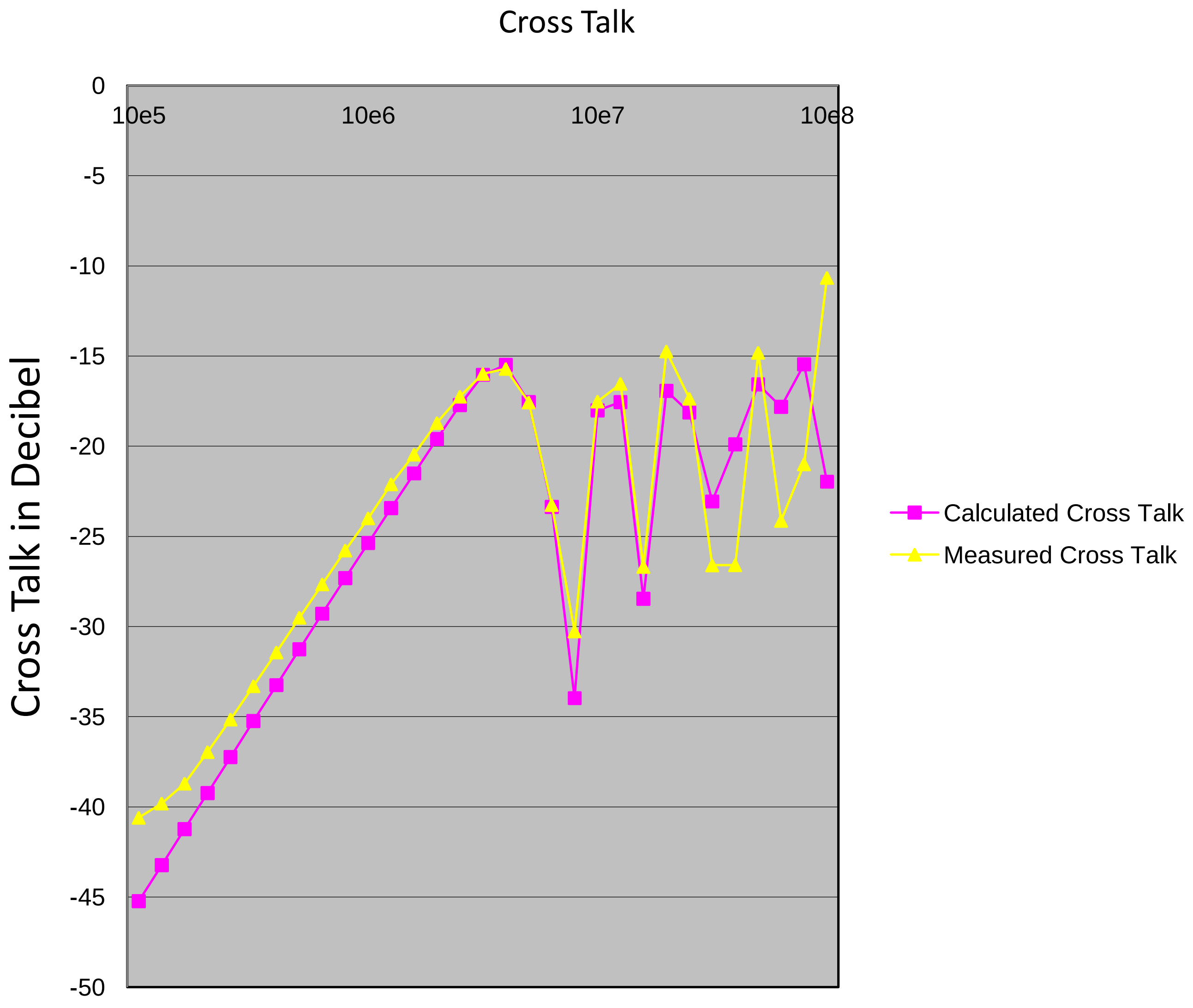
Cross talk measurement

LABELS	FREQ	XTKDB	MEASUREMENTS	V1 (mV)	V2 (mV)
10e5	1,00E+05	-45,2302	-40,59926447	2,1	225
	1,26E+05	-43,2311	-39,80909364	2,3	225
	1,58E+05	-41,2326	-38,70549341	2,6	224
	2,00E+05	-39,2348	-36,95641797	3,18	224
	2,51E+05	-37,2384	-35,15042498	3,88	222
	3,16E+05	-35,2441	-33,30223474	4,8	222
	3,98E+05	-33,253	-31,43141338	5,9	220
	5,01E+05	-31,2667	-29,50267267	7,3	218
	6,31E+05	-29,2878	-27,65261432	8,95	216
	7,94E+05	-27,3195	-25,77818726	10,9	212
10e6	1,00E+06	-25,3657	-23,9914471	13,2	209
	1,26E+06	-23,4297	-22,10644206	15,85	202
	1,58E+06	-21,5113	-20,45967814	18,4	194
	2,00E+06	-19,6053	-18,7091856	21	181
	2,51E+06	-17,7213	-17,24346482	22,8	166
	3,16E+06	-16,0441	-15,98387706	23,5	148
	3,98E+06	-15,49	-15,70468091	22,3	136
	5,01E+06	-17,554	-17,56393954	18,4	139
	6,31E+06	-23,3739	-23,25454595	11	160
	7,94E+06	-33,9712	-30,26237816	5,4	176
10e7	1,00E+07	-18,0114	-17,51590978	19,7	148
	1,26E+07	-17,5555	-16,53297557	15,8	106
	1,58E+07	-28,4588	-26,68541858	6,6	142,5
	2,00E+07	-16,9339	-14,7351713	18,7	102
	2,51E+07	-18,1294	-17,35921846	18,5	136,5
	3,16E+07	-23,0648	-26,60202887	6,5	139
	3,98E+07	-19,8967	-26,59293137	6,46	138
	5,01E+07	-16,569	-14,8104244	24,9	137
	6,31E+07	-17,8227	-24,13314501	9,6	154,5
	7,94E+07	-15,4549	-20,99543233	14	157
10e8	1,00E+08	-21,9686	-10,65574068	39	133

The measurement column is calculated with this expression:

$$\text{Cross talk (db)} = 20 \log \frac{|V_2|_{rms}}{|V_1|_{rms}}$$

We find also the following cross talk as a function of frequency:



THREE DECADES OF FREQUENCY STARTING FROM 100 kHZ

This measurement is not a good measurement, and I did not finish this project. Jérémy Brunet and Kevin Guillemet have finished their project.

6. Conclusion

We have work during a few days on the Cross Talk project. We have, with Arnaud Royer, helped Jérémy and Kevin in the first part of this project. Our measurement is bad, but Jérémy and Kevin have finished this project and it was perfect.

After doing the velocity and impedance measures, in the Even and Odd mode, we have calculated the TOROID cross talk. This measure allows seeing that the voltages and currents along a transmission line are different function of the frequency value.

If the measurement was great, the two graphics will be confused. Measured and calculated Cross Talk will be the same. Our experimental curve is lower than the theoretical because the arithmetic doesn't consider the loss in the cable.

During this practice, we have done the velocity and the impedance measures in the Even and Odd mode to realize the cross talk of this toroid.
We have found that the signal generator amplitude was too small. That's why the cross talk level is lower than the theoretical signal $2,51.10^{+07}$ Hz.
We have seen that transmission line losses are a different function of the frequency value.
The frequency value is important in EMC.

C. Apple project

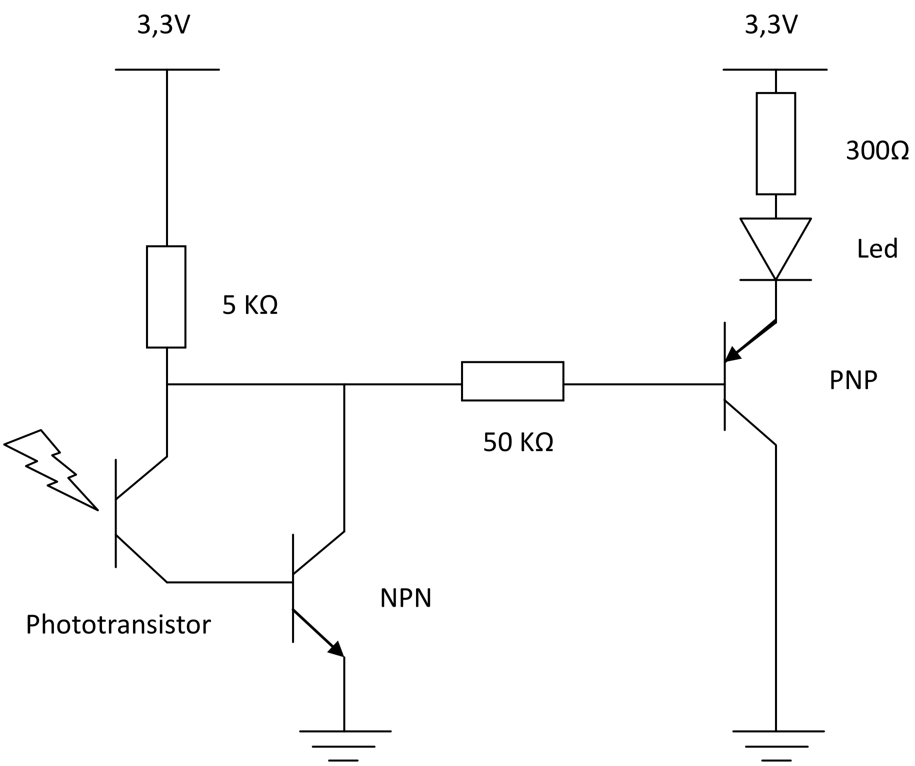
This project was the smaller, but not the less interesting. We have worked for apple during a week. Dr. Pommerenke want we do a system for the new Apple's batteries with a phototransistor. We have created a circuit on a virgin PCB.

We want to short-circuit the Apple's batteries with a fiber optic connection.

We used a phototransistor SFH3010-Z

1. Schematic

The schematic with the phototransistor is this one:



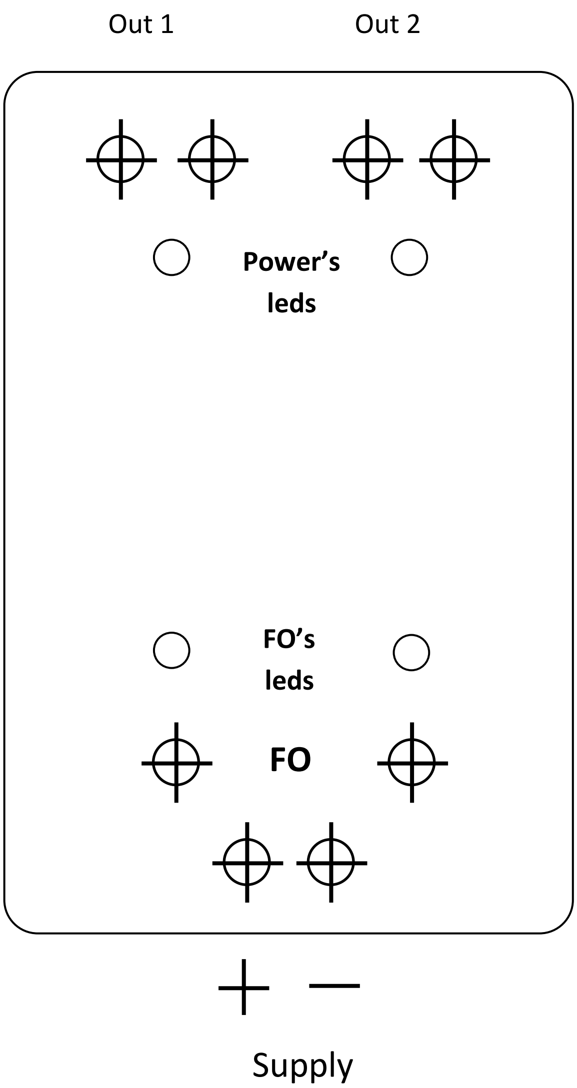
With this circuit, when the phototransistor doesn't receive light, the Led is off. And if we put on the fiber optic, the led will be on.

We had some problems with the fiber optic. If the values of the resistances was not great, the signal emit by the fiber optic was not enough.

2. The Box

We have created a box to take the project to Apple.

The schematic of the box is like that on the top:



Firstly, we have to make on the supply (5V). When the power is on the card, the Power's leds turn on.

If the **FO (Fiber Optic) is OFF**, the circuit is off and there is no signal in out 1 and 2.

If the **FO is turned ON**, the circuit is closed and the FO's leds are turned on.

On the box, we have made two cards. Apple wants to compare two circuits.

3. Conclusion

This project was a small project, but interesting because we had to research from the first to the end of this one. I have no pictures for this project.

We have to create the PCB, invent the circuit, and find what components it used.

After creating the PCB, we had to create the box for simple use in our project and for the aspect of the project.

V. Final conclusion

After three months in the Laboratory, I have learned a lot of things. It was very interesting to work in a real company on concrete project.

I think that this technical internship is very important for our studies. To me, this one was great. It was for me an occasion to learn in a lot of things in another country, and it was great for my English too. I have opened my mind because I have worked with people who come around the entire world. Learn and work in team is very important. Everybody have news ideas and it was good for our projects.

Dr. Richard E. DuBroff and Dr. Pommerenke were very present during these three months. It was pleasant to work with them.

I m satisfied because we have finished our projects and they work.

The Laboratory is very interesting because, you can see a lot of material. In this Lab, a lot of people would like to work, because the electronics' material and people who work in this lab are very interesting and very good.

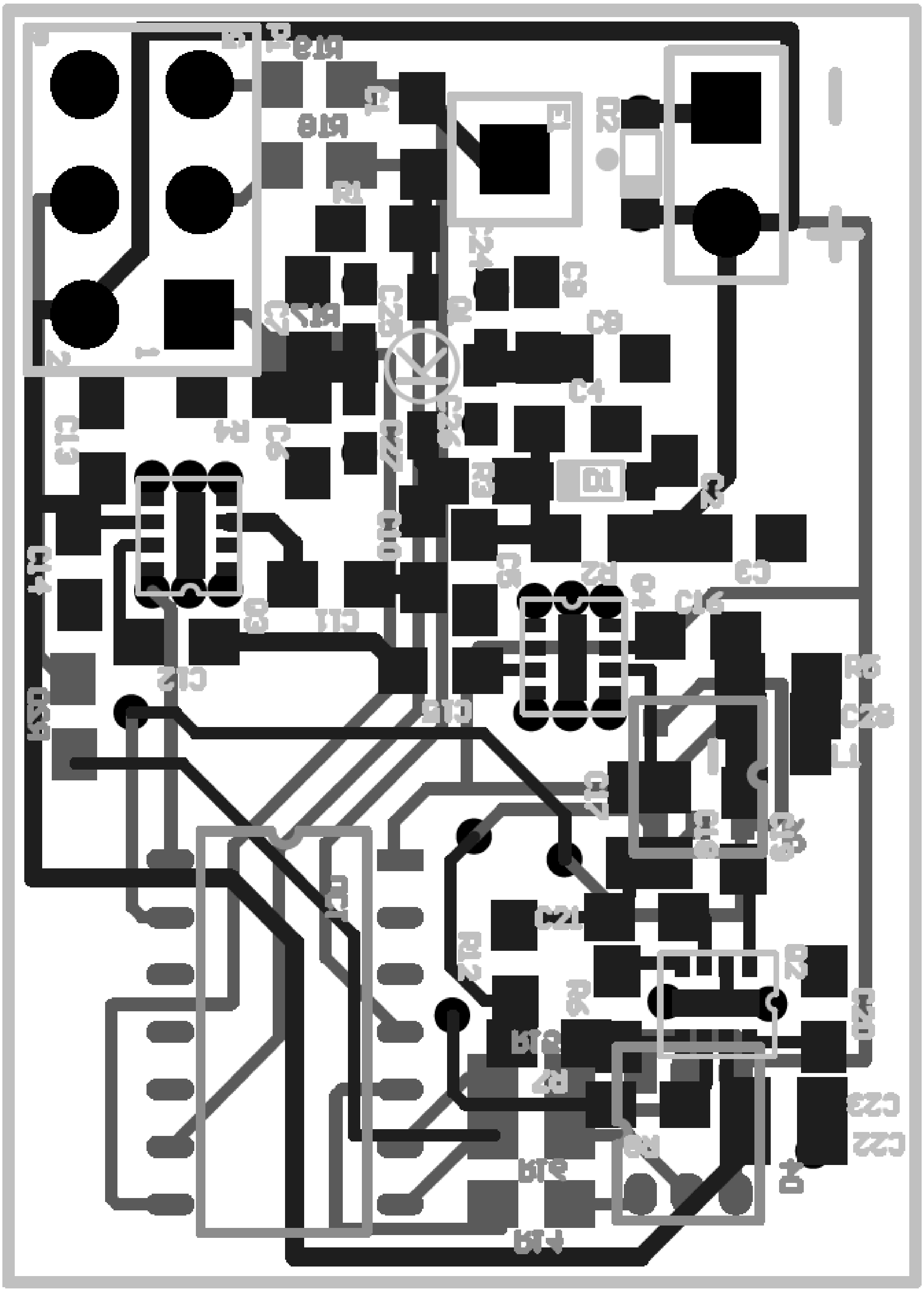
VI. Bibliography

- *www.wikipedia.fr*
- *http://emclab.mst.edu/*
- *http://www.mst.edu/*
- *http://www.polarinstruments.com/support/cits/AP157.html*
- *http://www.alldatasheet.com/*
- *http://futurestudents.mst.edu/explore/technology.html*

Annex

You will find in this part all annex documents about my three months in the MS&T Lab.

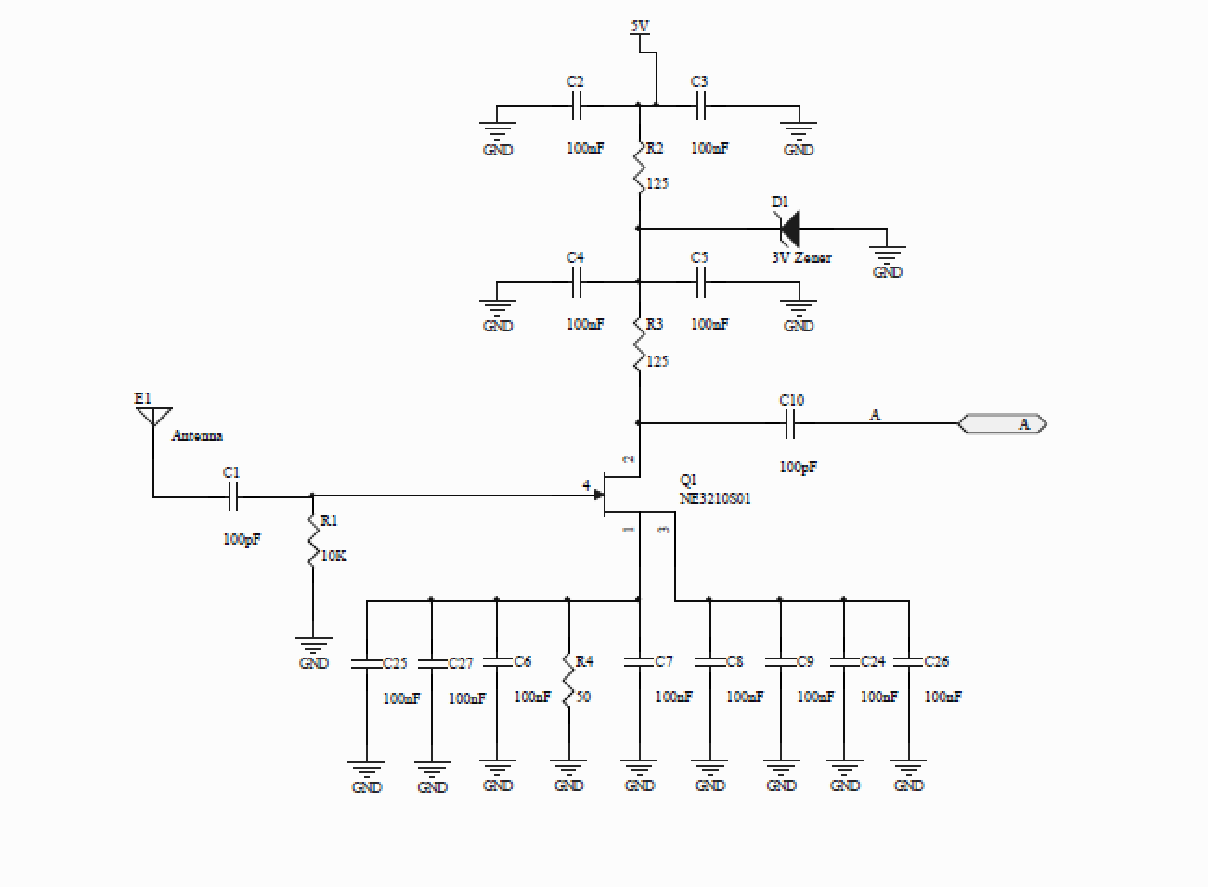
Annex 1: the map of the university



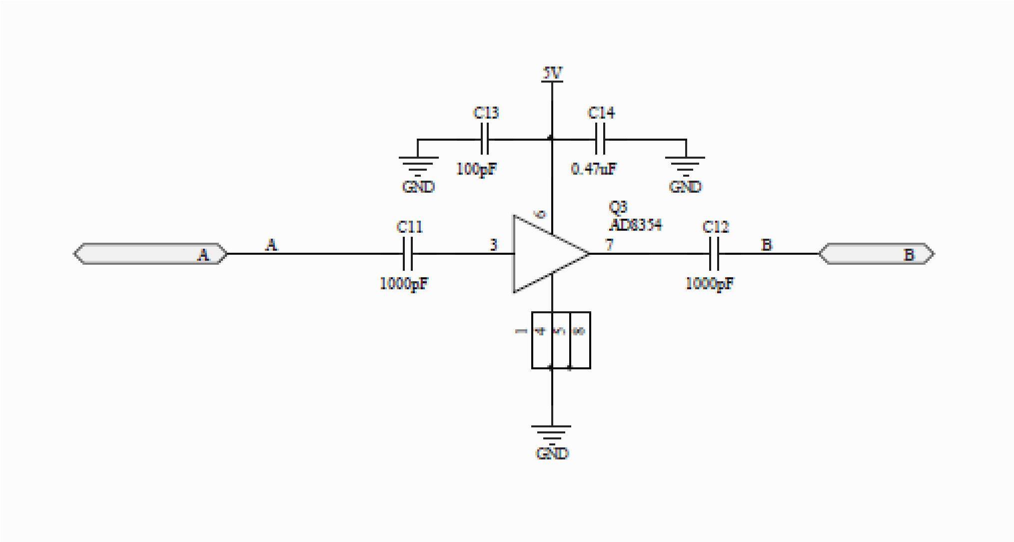
Annex 2: PCB prints

Annex 3: Schematic Prints

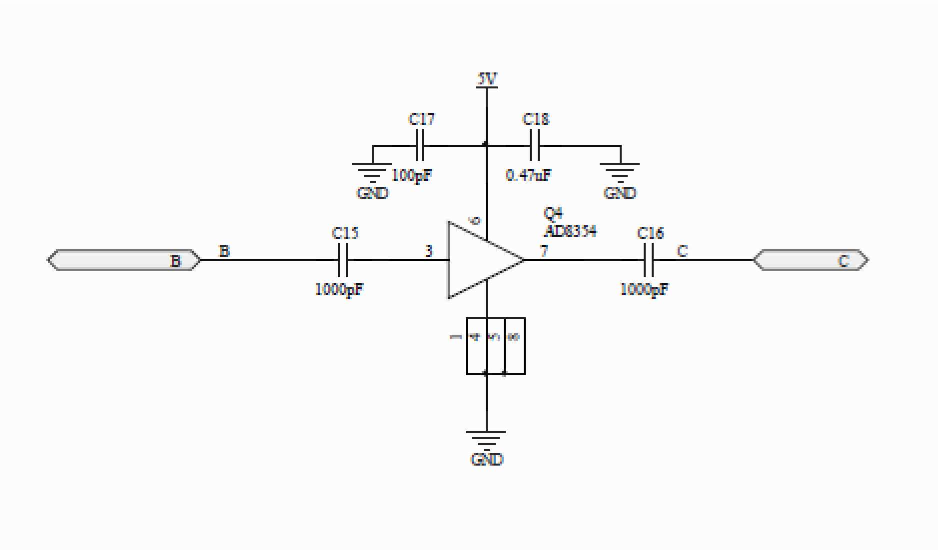
- Antenna buffer (stage 1):



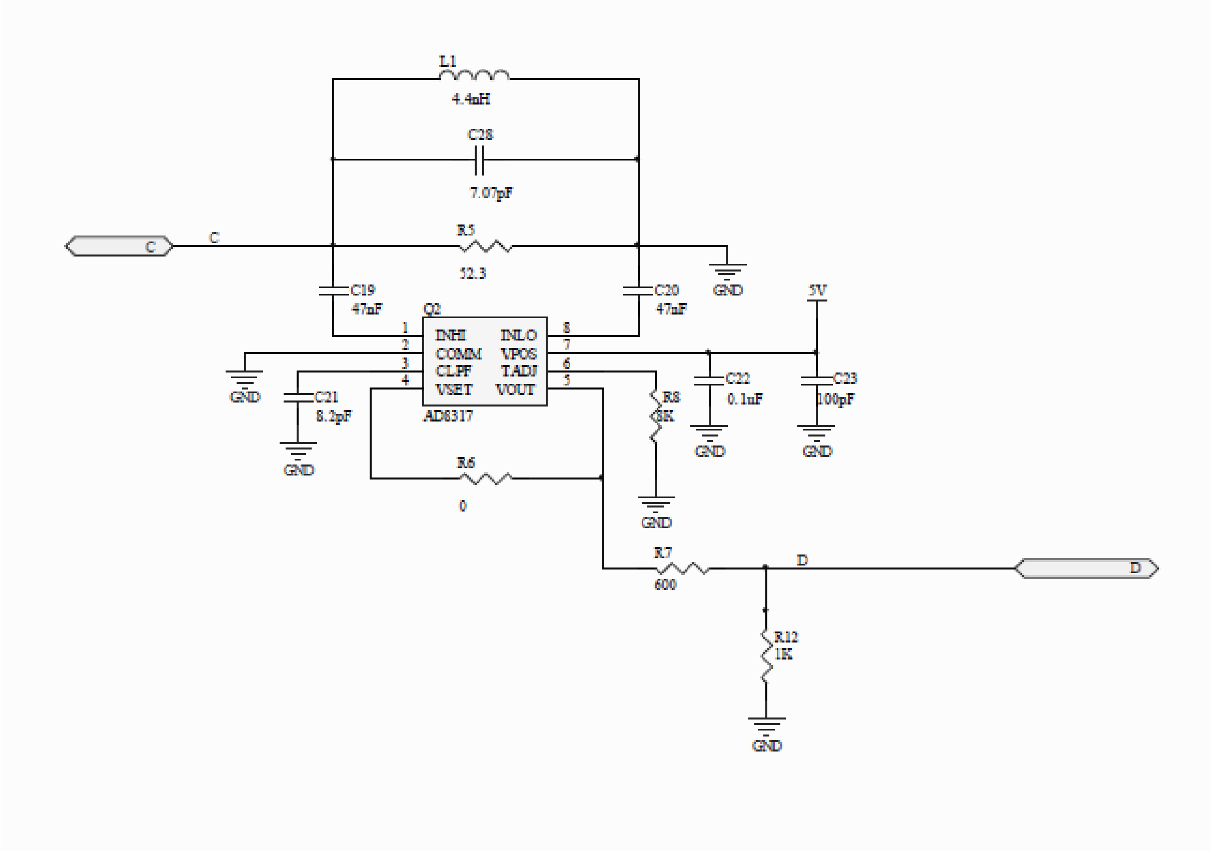
- Amplifier first level 20dBm (stage 2):



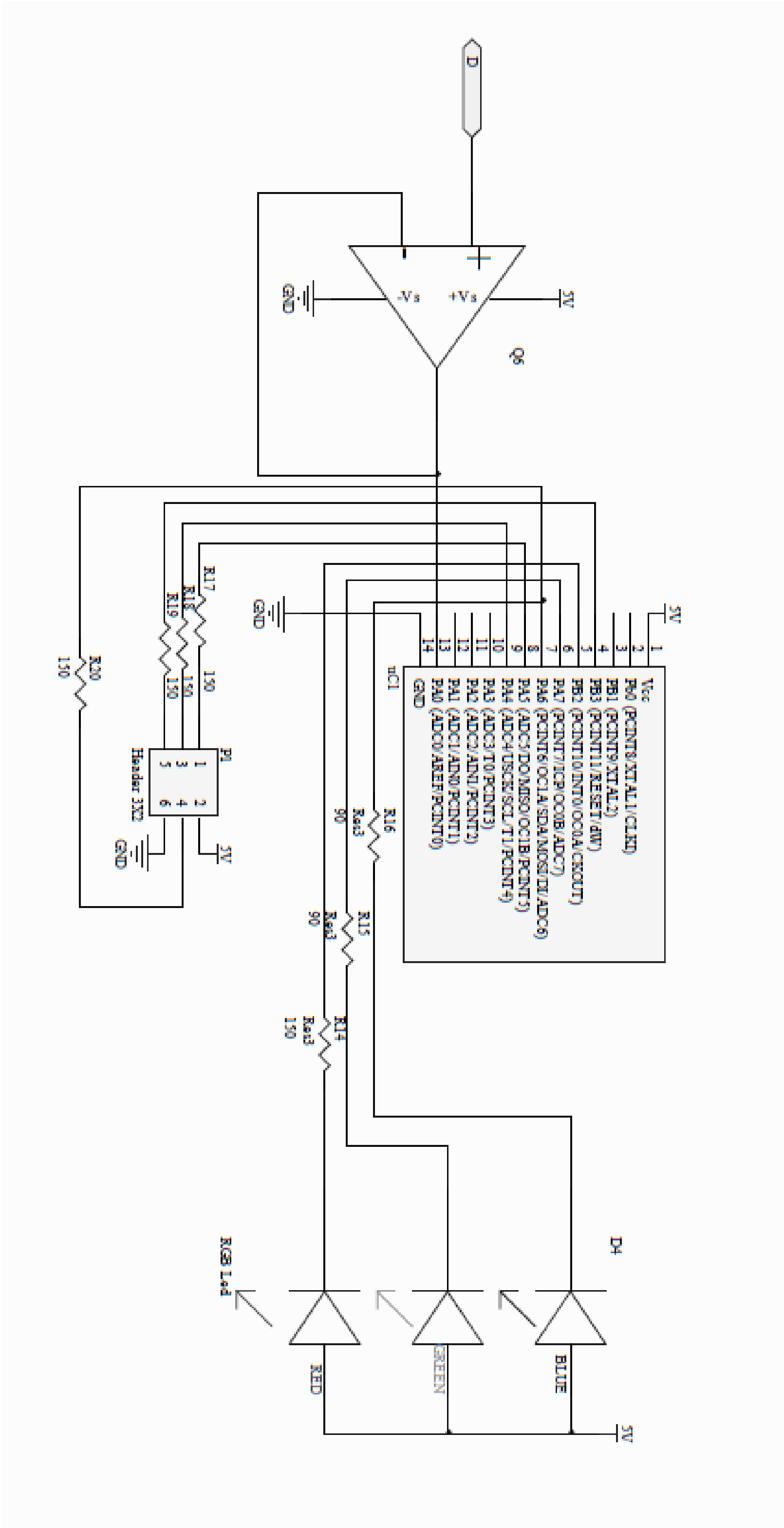
- Amplifier second level 20dBm (stage 3):



- Log detector (stage 4):



- Microcontroller (stage 5) :



Annex 4: Bill of materials

Footprint	Comment	LibRef	Designator	Description	Quantity
1608[0603]	Cap Semi	Cap Semi	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C28	Capacitor (Semiconductor SIM Model)	24
1005[0402]	cap semi	cap semi	C24, C25, C26, C27	Capacitor (Semiconductor SIM Model)	4
Sod 323	3V Zener	D Zener	D1	Zener Diode	1
Sod 323	D Zener	D Zener	D2	Zener Diode	1
RGB LED	RGB Led	RGB LED	D4	RGB Led	1
PIN1	Antenna	Antenna	E1	Generic Antenna	1
L0603	Inductor	Inductor	L1	Inductor	1
HDR2X3	Header 3X2	Header 3X2	P1	Header, 3-Pin, Dual row	1
HDR1X2	Header 2	Header 2	P2	Header, 2-Pin	1
SO1	NE3210S01	NE3210S01	Q1	SUPER LOW NOISE HJ FET	1
8-Lead LFCSP_VD	AD8317	AD8317	Q2	LOG DETECTOR	1
8-Lead LFCSP_VD	AD8354	AD8354	Q3, Q4	20dB RF GAIN BLOCK	2
SOT-23	R-R Op Amp	AD8061	Q6	300 MHz Rail-to-Rail Amplifier	1
J1-0603	Res3	Res3	R1, R2, R3, R4, R5, R6, R7, R8, R12, R14, R15, R16, R17, R18, R19, R20	Resistor	16
SOIC14	ATTINY84	ATTINY84	uC1	8-bit Microcontroller from Atmel	1
					57

Annex 5: sphere schematic