SpaceCom Team One
Design Document

Mission Objectives

As more and more satellites are being sent in space and drones are getting cheaper the need for tracking and data links is rising. Devices like the one we are building in the project can be useful to almost everyone who needs a long distance communication with another device. Even radio astronomy can benefit from such systems because they are similar to radio telescopes. The project goal is to develop a satellite tracker for the period of 6 weeks. In the end of the project the tracker should be able to download data from a weather satellite.

Bellow are listed the objectives of the mission.

Primary objectives:

- Tracking movement
- Receiving EM waves
- Reading the received information

Secondary objectives:

- Receiving transmission from the ISS
- Using the device as a radio telescope

The idea

Our main goal is to create a mechanical system which can hold an antenna and be rotated in any direction above the horizon. This means that it should rotate on two perpendicular axes. First we guarantee the horizontal rotation by holding the entire antenna on an upper plane fixed to the main rod of our device which is vertical. This way it will be able to do a 2pi rotation. Second we put another rod on the upper plane and a secondary rod which is horizontal and does a pi/2 rotation which gives the antenna the ability to see objects at any height. Our antenna should be able to receive 50dBm signals. Using satellite position data from internet we will give commands to the motors to direct the antenna in the proper direction, try to download information and if successful write it in the device's memory.

Description of the parts

Wooden parts:
45x45x2cm upper plane made of particle board, 24.5x24.5x2cm middle plane made of particle board, 20x20x2cm upper plane made of particle board, four 44x3.5x3cm ground legs made of wooden planks, four 8x2.4x10cm plane legs made of particle boards, two 83x90x2 rectangular rod holders made of particle boards.
Metal parts:
70x2cm, 1.8cm inner diameter aluminum cylindrical main rod, 30x2cm 1.8cm inner diameter aluminum cylindrical secondary rod, two 100x1.5cm- 1.3cm inner side square pipes, twelve 26x26x10mm brackets, four straightened 11.8x3cm brackets, four 4cm outer, 2cm inner diameter bearings, bolts and wooden screws.

Building process

Tracker

We drilled holes 4cm in diameter in the lower and middle plane and situated bearings there. The wood was peeled just enough for the bearings to be stuck inside. On the lower plane we drilled holes on 8.5cm and 14.5cm from the center on the diagonals (8 holes). We cut four 8x2.4x10cm plane legs and made holes on their 10x2.4 sides on the middle (1.2cm) of the shorter side and 2cm from each end on the longer side.

Every leg is held in place with a pair of wood screws on each of the pairs of holes on the lower plane. On top of the legs (2.4x10 side which still doesn`t have holes) we drill a hole in the middle. On these 4 holes we put the middle plane using wood screws. It took some adjusting but we situated it perfectly symmetrically so the 2 bearings are aligned. The main rod goes through the 2 bearings and can now only rotate around its axis of symmetry.

On the diagonals of the 45x45 plane we measured 10 cm from the edge inward and at that point perpendicular to the diagonal 1cm on each side. We cut that “2x10cm hole” on each of the 4 sides to create space for the ground legs. Positioned in a way that assures free motion of the legs brackets are put one on each side of the holes (8 brackets). The ground legs are then screwed in this order screw – bracket – nut – washer – ground leg – washer – nut – bracket – nut. The legs are 44x3.5cm.

The upper plane is attached to the main rod using two 26x26mm brackets with two bolts going through the rod and one wood screw on each bracket connecting it to the plane. Symmetrically on the two edges we have attached rod holders (standing on the longer side) with 4cm holes for bearings. Through the bearings we put the secondary rod (similarly to the main) which sticks out 4.9cm on each side. On these 4.9cm we used bolts to attach 4 straightened brackets two on each of the 4.9cm parts on the opposite sides of the rod. On the brackets on each side we attach 1.5x1.5x100cm square rods using the same bolts on 42cm from the end of the rods.

Motors

Motor positioning algorithm – we positioned the first motor on the lower plane using 2 8cm long bolts (which we later cut to the proper size) Motors are manipulated using drivers, controlled by Arduino nano. They work by using the dir pins – dir – direction and step – step by which the driver “tells” the motor the direction in which to rotate and how much. The pins are digital and work with 0 and 1. To rotate clockwise dir – 1 and counterclockwise dir – 0. To complete the rotation step has to receive 1 – to rotate 1 step. Afterwards it`s important to send 0 so that you can avoid burning the controller and to prepare him for the next step. With 200 steps resolution this means that after 200 1s the motor will have rotated a full 360 degrees. Here we come across the 1/n stepping it allows the driver to rotate the motor with lesser than 1 step angles (1/8, 1/16, 1/32) which brings the resolution to 200*16 steps (0.1125 degrees). The process is completed using 3 pins – ms0,ms1,ms2 which according to the signal receive 1 or 0 and thus determine the micro steps. We used DRV8825 driver but it can be switched with another driver. To get an even better resolution we used different diameter chain wheels and pulleys. The corresponding ratio is 2.5/1 so we get a minimum rotation of 0.1125/2.5=0.045 degrees.

We screw down the motors to the lower and upper planes.
10.5x20.5 first bolt from the tip of the lower base (any tip works due to symmetry) 45mm second bolt towards the center (diagonal bolts on the 4 holes square on the bottom of the motor 32mm apart – 45 mm diagonal).
On one of the rod holder we make two holes 32 mm apart for the second motor. (position is a bit random since it`s the only component there are there is a lot of space)
We 3d printed two pulleys and two chain wheels for each motor a representation of which is shown on the picture. The pulleys were attached to the motors and the chain wheels to the main and secondary rods. We used 2mm edge to edge belt to connect the pulleys to the chain wheels. It didn`t fit perfectly but it worked very well which shows that the device can use spare parts for other machines.

The motors, drivers and Arduino are connected as follows:

The tracker`s electronics need 16V DC power supply. For now we use an adaptor connected to the grid but we are considering using batteries in the future.
The maximum oriented mass can be up to 8 kg (without the counterweight) and we have tested this with water bottles.

Antenna

To create the antenna we used this guide http://www.g4ilo.com/qfh.html and this calculator http://jcoppens.com/ant/qfh/calc.en.php#ad1c .NOAA weather satellites operate around 137 MHz and the antenna we built works great on these frequencies (we tested it but unfortunately they were no good satellite passes to gather some real data). We chose a quadrifilar helix antenna because it has a higher gain than most other antennas and also many guides online recommend it. The antenna is omnidirectional – it doesn`t need tracking. To summarize the process we use these several schemes and several images show the end result. The corresponding lengths are shown in the tables and positions are shown in the schemes. The tubes have diameters – 3cm for the mast (which is 15 cm longer so that it can be attached to the tracker), 2cm for the separators. The cable going around the antenna (larger and smaller loops) is 2mm regular cable and the coaxial cable is 5mm braid, 2mm middle. The cables have been soldered according to the scheme shown below. We plan to receive NOAA satellite weather data with the antenna and turn it in to images with the ADP decoder program which offers a wide variety of FM, AM, satellite and many other signal reading options. To protect the antenna from the Sun’s UV light we intend to use it under the ozone layer. Still the plastic components may decay so we plan to cover them with aluminum foil.

The end result:

To connect the antenna to the tracker we used the square pipes. Using two 26x26x10mm straightened brackets we squeeze the mast between the square pipes. The bolts used are 3mm thick and the holes are 1cm from the ends of the square pipes. The second stationary point is created by fixing a 15cm elbow 20 cm from the ends of the square pipes again with 3mm bolts. In the middle of the elbow and the end of the mast we drilled holes and a zip tie holds them together. To secure the square pipes from holding we put another 70cm elbow on the other side of the upper plane of the tracker 10cm from their other ends again with 3mm bolts.

Business plan

Customers

Considering each application it`s obvious who may want to buy the system.
Using it as a radio telescope - several schools in Bulgaria have any telescope. Since our device will be cheaper than most telescopes in visible wavelength it will be an option to consider and expand the astronomy and space education. We will have to talk to each principle in person and use the national physicists' union web site to reach more physicists teachers.
Using it as a satellite tracker – nowadays many ground weather stations in Bulgaria are being closed because NIMH BAS doesn`t have the money to keep them going. Our device can help with downloading weather data from satellites faster. We will need to talk to the representatives from NIMH BAS.
Using it as a drone antenna – we could ask for help from eBay, Amazon, Ali Express to display our creation on the drone related equipment pages.
Using it as a plane tracker – few trips to Gorna Oryahovica and other small airports will help us learn more about the specific requirements and needs of the sector.

Production and price

**Until the last line assume that we work from home (rent=0$).*
To create the tracker we had 20 hours of research and 40 hours of work. If we mass produce the device the research time will become neglectable and the work can be cut down to 20 hours (20*3=60 workpersonhours) now that we know exactly what we need and how to create it. Still given full work day this sums up to two devices per week. We needed 22$ for motors, 3$ for Arduino, 10$ for drivers, 45$ for mechanical parts, 3$for electricity sums up to 83$. We believe that if we are really conservative we can get it down to 70$ and try to sell it for 100$ apiece but even if we succeed this makes 270$ profit every month – 90$ per person before the taxes – not a good plan. Still this concerns only the tracker. This is if we succeed in selling 100% of our production. To compensate for that let`s say we sell at 60% the described rate. This is changes the profit approximately from $ to lev – 90 levas per person per month. Speed – one tracker every 2.5 days, 100$ per tracker. This is the only price we could find for another tracker but it uses cheap and breakable materials and doesn`t have many options like smartphone and camera attachment which we will have. Advantage – customable and robust.
https://www.youtube.com/watch?v=OWVYkT2ZNFw – 50$.
The antenna used is omnidirectional. This means that the antenna doesn`t need the tracker. We can produce the antenna for around 25$ and the antennas closest resembling ours we found on this site http://www.wxtoimg.com/hardware/ . Here we see antennas with similar properties sold for 150$. We can produce 10 antennas every 40 hours and they admittedly will not look really good but even if we sell them for 100$ we will still profit 750$ every week which is around 3300$ each month – 1100$ per person before the taxes – this is a big salary by Bulgarian standards and it will work. Again let`s say we sell at 60% the described rate. 1100 levas are still a good salary. Speed – one antenna every 4h, 100$ per antenna. Advantage – cheaper.
In general our product is better than anything on the market because:
Different mounting capabilities

- Satellite dish
- Camera
- Smartphone
- Heavier receivers

Geopolitics

- Most if not all suppliers are in the US

For the entire tracker we can start producing most of the parts with 3d printers which will lower their cost, bring up the electrical energy needed and we could speed up the process using several printers and one person to operate the printing and assemble the pieces. We believe we could get the price down to 25$ for mechanical parts and up to 5$ for electrical energy. This is around 65$ for the entire device now if we still sell it 100$ apiece this makes 310$ before the taxes but for only one person (310 levas).

If we start with only antennas and 600 levas salaries and build our factory from our profits only we could buy 2 3d printers on the second month (http://n.stuccu.com/s/Makerbot%203D) which puts us in a good position considering the tracker market and we could expand to new employees and afford rent and in approximately one year go to 2000 levas salaries and look for new opportunities. (considering we pay the employees 90% of what they earn which is still high).

Team members

Mihail Georgiev – buying materials, software, soldering, tracker hardware.
Yavor Mihailov – buying materials, software, tracker and antenna hardware.
Tsanimir Angelov – keeping track of things, writing the design document and presentation, antenna hardware.