TFE4850 - EiT - Student satelite

Groundstation network

Group 2
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Abstract

This project aimed to create and test a BlueBox, an USB-driven ground station, developed for AAUSAT3 by Aalborg University to send and recieve signals from satelites. The NUTS project have a problem with low transfer rate between the single ground station at the university and the satelite, and by setting up a network of BlueBoxes at different ground stations around the globe, we can increase the time which the satelite is available for data transfering.

Since setting up the network proved too time consuming, we set as our goal to make a BlueBox, and test that it can recieve signals from a satelite, and in this way make it easier for others to set up the network, in that they already have documentation on how to set up and configure each indiviual ground station.

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Chapter 1

Introduction

This chapter will contain a short introduction to our project. That means what we're doing and what people are working on the project. It will also be discussed some short background on why we're doing this project.

1.1 The Project group

The project group consisted of 6 people from 5 different directions, so we had a wide variety of competance to use in the project. The group members can be seen in **??**.

Name	**Background**
Marius Ekerholt	Computer technology
Eirik Skjeggestad Dale	Computer technology
Hanne Thorshaug Andresen	Energy and Environmental technology
Leif-Einar H. Pettersen	Electronics and Telecommunications
Børge Irgens	Theoretical Physics
Hallstein Skjølsvik	Electronics and digital design

Table 1.1: Group members

Chapter 2

Theory

Before we started our project, we did quite alot of prestudy, covering which technology was available, to determine which fit our project best. This chapter will contain a summary of the different technologies, and also some theory behind the reasoning for having multiple ground stations listen to our satelite.

2.1 Communicating with the satellite

Since we don't know when the satellite will be launched we don't know the exact orbit. The project manager, Roger Birkeland, told us that we can assume the orbit will have a height above the Earth somewhere between 450km and 650km and inclination of 98 degrees.

The height above the earth dramatically changes the time the satellite is seen by the ground station, see Fig. 2.1. The signal will be weaker when the satellite is further away, it is therefore necessary to increase the minimum elevation angle ϵ, see Fig. 2.2, to maintain SNR. Previous work[**?**][**?**] has calculated the minimum elevation angle, for a ground station here in Trondheim, for satellites with different altitudes and found that these effects cancel each other out. In the following we'll assume that the altitude is 500 km and the minimum elevation angle is 28 degrees.

The result of this is that the ground station can communicate with the satellite whenever the ground track is inside a rough circle centered on the ground station, see Fig. 2.3 for the estimated "range" of the ground station at Gløshaugen operating with these constraints. The efficency of a network of ground stations is reduced when the ranges overlap, so to have a efficient network the nodes must be geographically far apart. In this case the ground stations must be more than 1600 km apart to have maximum efficency.

The Gløshaugen ground station will on average be able to communicate with the satellite 520 seconds per day. The precise amount of data that must be downloaded is unknown (*Her mangler litt*)

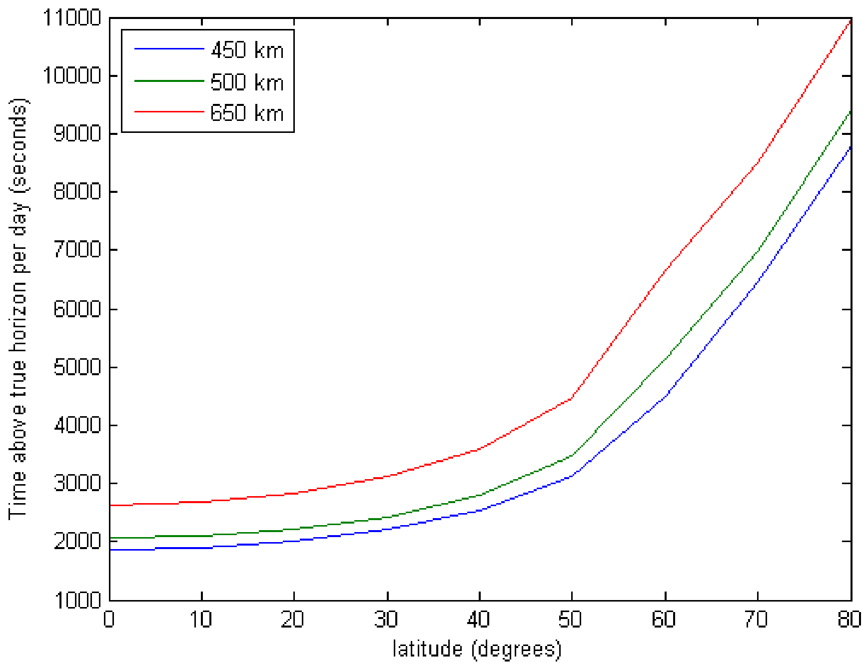

Figure 2.1: Time above the horizon for a satellite with altitude $h = 450km$, $h = 500km$ and $h = 650km$ as a function of ground station latitude

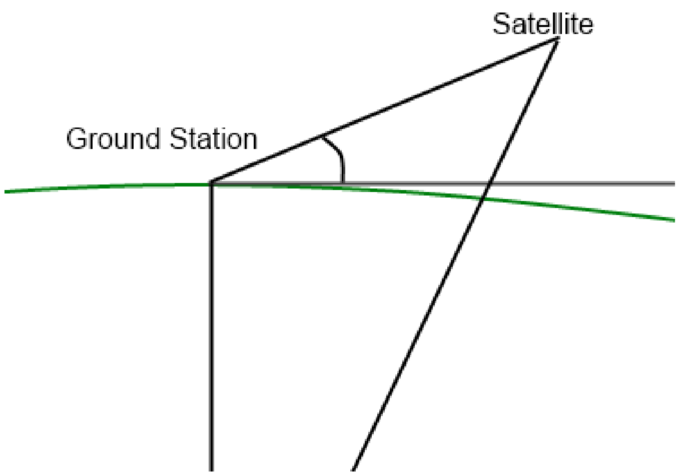

Figure 2.2: Illustration of geometry between a ground station and a satellite

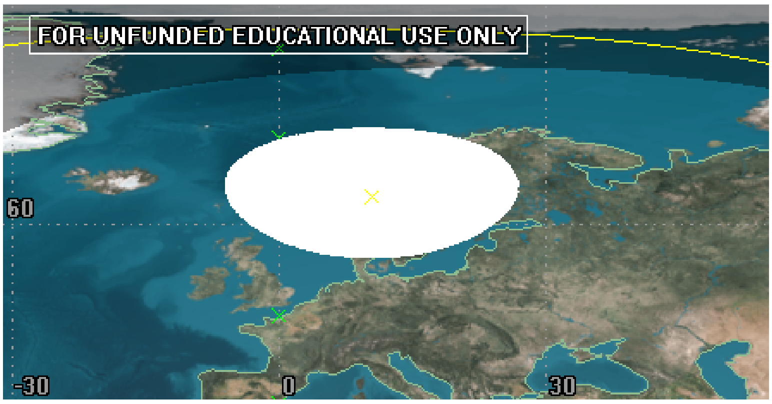

Figure 2.3: NTNU ground station range

2.1.1 Other ground stations

2.1.2 Other ground stations

Fig. **??** shows that the access time for a (near) polar satellite is almost latitude independent for ground stations at latitudes below 45 degrees. The access times of a ground station those low latitudes are about about 280 seconds/day, i.e. half the duration we get here in Trondheim. For higher latitudes the access time increases dramatically. And the average access time for a ground station in Longyearbyen (78N) is in fact as high has 1300 seconds/day.

2.2 Network technology for ground stations

When we decided to work on a network of ground stations, we first looked into four different ground station network technologies. We first hoped to work on a BlueBox, but this would require support from Aalborg that we couldn't get, as they were busy with a satelite launch of their own. Because of this, we decided to look into Carpcomm, that seemed more complete and doable than connecting to PYXIS with a BlueBox.

2.2.1 Pico

information about Pico

2.2.2 Genso

GENSO is an abbreviation for Global Educational Network for Satellite Operations. As the name suggest GENSO is a network where satellite operators across the world can utilize each others ground stations. GENSO provides

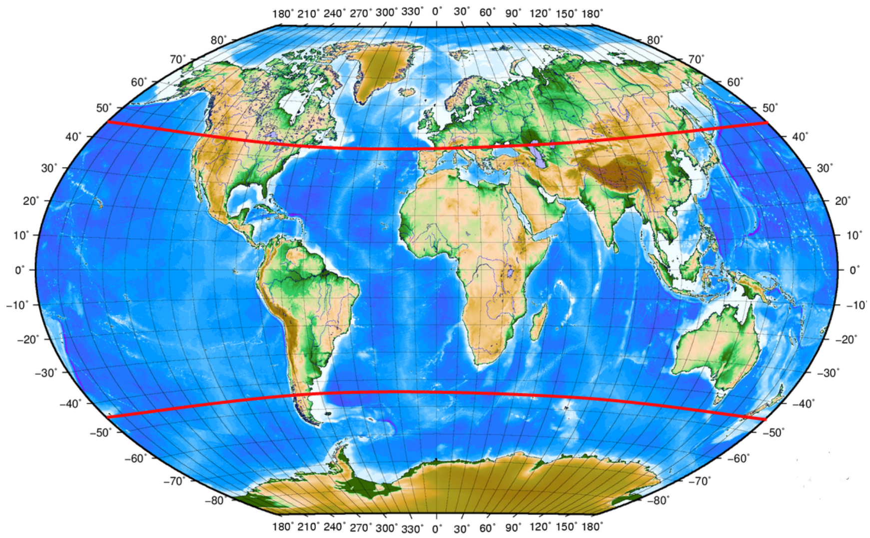

Figure 2.4: Map of the World

a stable network by the use of several Authentication Servers (AUS), that will synchronize with each other. This will make the network resistant to single point failures. As user of GENSO a software applications is available. This is the Ground Station Server (GSS). A GSS application allows Mission Control Clients (MCC) in the GENSO network to connect to the ground station and download data from space crafts. If the space craft is able, and local laws permit, it is also possible to upload data[7]. Figure 2.5 illustrates this set up.

At first glance GENSO seems like a well organized ground station network which corresponds to the network we want to join. However it is difficult to find anything about the development of the project since September 2010. In addition the GENSO home page "GENSO.org" is not operational. Due to the difficulties with finding information of the current state of GENSO, we chose to look for other alternatives.

2.2.3 Carpcomm Space Network

Carpcomm is a private company that delivers a plug and play ground station [3] that costs $700. The software for the ground station is open source and is provided pre.compiled for x86 and arm debian. It is compatible with the Carpcomm Space Network [4]. The advantage of using this solution is that the network is actually functioning, though there are few other operational ground stations.

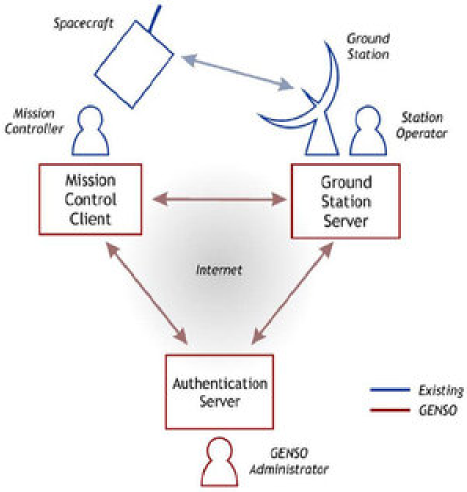

Figure 2.5: Illustration of the GENSO network.

2.2.4 PYXIS

The BlueBox is part of a distributed ground station network called PYXIS, developed primarily for the AAUSAT3 by Aalborg University (2013 [2]). The PYXIS goal is to offer a robust and effective ground station network for satellite developers, and one of the key factors is that everyone is free to setup a ground station using the open source BlueBox hardware.

The PYXIS concept includes a backend server, BlueBox hardware and a Ground Station Server (GSS). The backend server runs an individual instance for each satellite utilizing the BlueBox, and is operated by the persons responsible for the ground station.

The BlueBox itself is hardware to recieve and transmit signlas from the satellites.

Control of the BlueBox and ground station mechanics is handled by the GSS, and both the BlueBox and the GSS is operated by the responsible for the Ground station.

Both the backend server and the GSS is already in place at each ground station, and to join the PYXIS network we would only have to make a BlueBox, and test that it works.

2.3 Raspberry pi

Raspberry Pi is a small computer, with everything gathered in one board. In our project we will be using the B model, revition 2, which have a 700MHz ARM CPU, 512MB of RAM and a SC-card reader, in addition to the leads to connect to different devices, for the full overview, see figure 2.6. The

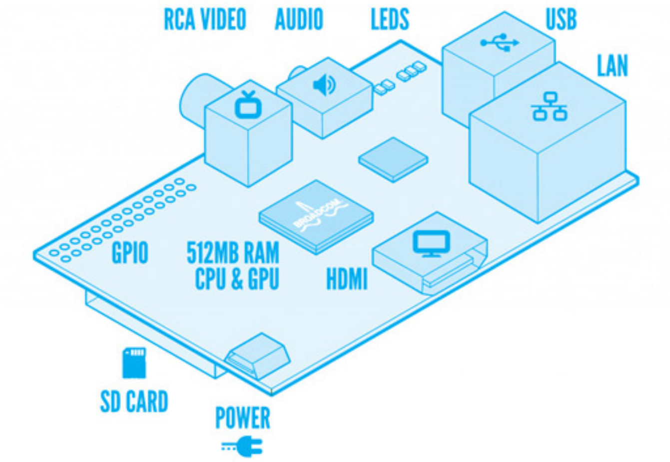

Figure 2.6: A highlevel schemantic of the Raspberry pi, mobel B rev 2

recommended operating system is Raspbian, a linux distribution based on Debian.

The Raspberry pi was originally intended to help teach programming, but it can also perform many of the standard computer tasks, and it can be connected to a monitor or tv using an HDMI lead. In our project we hope to be able to use a Raspberry pi to run the software required to control the ground stations. The software provided by the carpcomm project has Raspbian as one of its supported plattforms, so we hope this will work well.

To control the movement of the antennas, an serial port is needed. Raspberry Pi has an serial port included in its gpio (general purpose input/output) connector. This serial port uses ttl-standard for its voltage levels, this is 0/3.3V while RS232 which is the standard used in computers uses (3V-15V)/-(3V-15V). Because of this an converter is needed. We chose to make an custom circuit board using the MAX3232 RS232 line driver. The circuit board is designed to be mounted on the gpio connector, because of small space in the case for the Raspberry Pi, the output is connected with cable to the external connector.

2.4 SunPower

When a satellite communicates to its groundstation and operates its payload it is dependent on power supply. Without any electrical power a satellite will have noe function other than to drift around in orbit unable to communicate. NUTS double CubeSat uses sunlight as an energy source through solar panels.

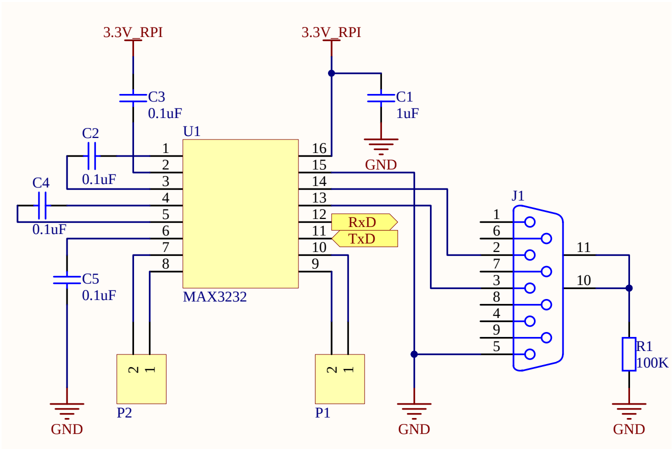

Figure 2.7: Schematics for the RS232-converter

Solar panels base their operation on the ability to convert sunlight into electricity by exploiting the photovaltaic effect by using semiconductors. The convertion process where the suns radiation is converted into an electical current is achieved by creating mobile charged particles in the semiconductor. They are in turn separated by the device structure and produce the electrical current.(kilde) The use of photovaltaic solar generators is the best choice for providing electrical power to satellites in an orbit around the Earth (kilde: Solar Electricity, page 180, kilden skal skrives ordenlit!).

To get information on how long communication time the CubeSat can achiece through a ground station network the energy supply must be calculated.

Batteries are used to preserve power during eclipse to support the payload. When calculating the battery power the eclipse must be taken into acount. When the sun is blocked from the satelite by the earth the battery is accountable for the power during that part of the orbit. Communication with the stelite thorugh the groundstation network demands power from the satelite. The power budget and the battery power need to be established.

When estimating the maximue time the satelite spents in one orbial period the earth and orbit is assimed to be spheres. Kepler's third law for circular orbits is used:

$$\frac{4\times\pi}{t^2} = \frac{GM}{R^3}$$
$$t = 2\times\pi\times R_{sat}\times(\frac{R_{sat}}{M\times G})^{\frac{1}{2}}$$

Universal constant of gravitation: $G = 6.6742\times10^{-11}\frac{km^3}{s^2}$

Earths Mass: $M = 5.9736 \times 10^{24}\ kg$
Radius of the Earth: $R_earth = 6371km$
Distance from to the satellite: $R_sat = R_earth + h$
Orbial Hight: $h_1 = 350km, h_2 = 650km$

Since it is uncertain what altitude the satellite will settle in after it is launched, two hights is used in the calculations assumed that the satellite wi settle in this interval.

$h_1 = 350km$
$t_1 = 5482.5s = 91.4min$

$h_2 = 650km$
$t_2 = 5854.1s = 97,6min$

From Dewald De Bruyns equations one can calculate the longest possible time in eclipse. The worst case average power is approximately $P_{avg} = 5.42W$ from by De Bryens calculations.

$t_{ecl,max} = 2 \times R_{sat} \times (\frac{R_{sat}}{R \times M})^{\frac{1}{2}}$
$P_{avg,orbit} = P_{avg} \times \frac{(t - t_{ecl,max})}{t}$

This becomes for each of the possible heights:

$t_{ecl,max_1} = 2175.75s = 36.3min$
$P_{avg,orbit_1} = 3.27W$

$t_{ecl,max_2} = 2118.9s = 35.3min$
$P_{avg,orbit_2} = 3.46W$

These are simpliefied calculations where the teperature changes of the solar cells is not taken into account. As the satellite moves through orbit the temperature will effect the solar cells, but this requires more extensive calculations. The average power calculated here is based on worst- case estimate and the real average power can be clculated with the exact orbital parameters.

The battery used in the NUTS Cubsat wil consist of lithium-ferrite-phosphate cells ($LiFePO_4$). These cells have a typicall voltage of 3.3 V. The Cubesat has $4 \times 1.1Ah$ cells, where two is in serie and two is in parallel. This means a total of $2.2Ah$ at $6.6V$. This is used to calculate the worst-case Depth Of Discharge (DOD). The DOD represents the percentage of the discharged battery capacity expressed as a percentage of maximum capacity. It indicate the state of charge where 100%= empty and 0% = full.

Total capacity: $C_{tot} = 2.2Ah$
The battery capacity used during eclipse: $C_{ecl} = \frac{P_{avg,orbit}}{V_tot} \times t_{ecl,max}$
$DOD_{max} = \frac{C_{ecl}}{C_{tot}}$

Calculted with the different hights give:

$C_{ecl_1} = \frac{3.34W}{6.6V} \times (\frac{35.9min}{60\frac{min}{hour}}) = 0.303Ah$
$C_{ecl_2} = \frac{3.46W}{6.6V} \times (\frac{35.3min}{60\frac{min}{hour}}) = 0.32Ah$

Chapter 3

The project

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