Ardumower Sunray

From www.wiki.ardumower.de

'Mows like on rails...' This is an experimental RTK GPS-based mower that you can build yourself. Ardumower RTK **doesn't need a perimeter wire** as it uses (cm-precise) RTK GPS.

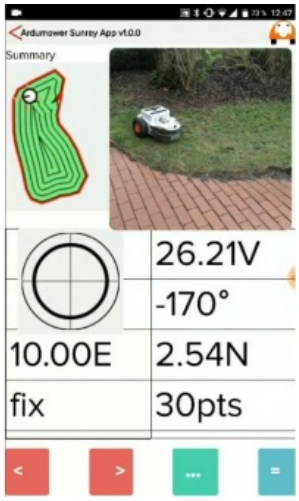
Key features:

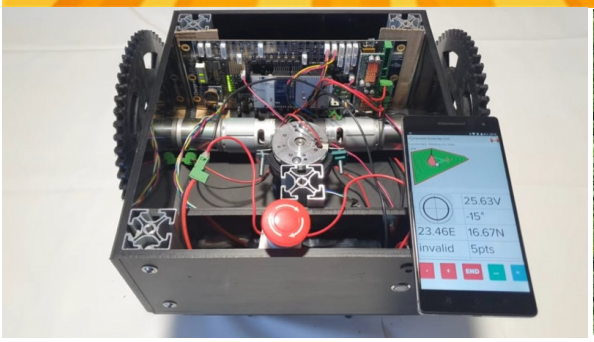
- **No perimeter wires** (cm-precise GPS)
- **Obstacle detection via**: ultrasonic, bumper and GPS feedback
- **Single mowing unit ground coverage performance** (0.4m/s or 1.5km/h, 18cm path offset) : 100 qm per hour / 2400 qm (=0.24 hectare) per day
- **Maximum supported ground coverage (by CPU memory) for maps:** 600m x 600m (36 hectare)
- **Overall power consumption (average)** with single mowing unit: 40W (60W peak, 7W idle)
- **Single battery (125Wh) run-time (average)**: 3 hours / double-battery (250Wh): 6 hours

This page describes **how to build your own (experimental) RTK-GPS mower**. It requires an **Ardumower DIY robotic mower system (https://www.ardumower.de/index.php/en)** and a **RTK-GPS kit (https://www.marotronics.de/Ardumower-GPS-RTK-Kits-GNSS)**. You can get the RTK mower as a whole kit in the shop too (click here to get the RTK mower or just the RTK kit (https://www.marotronics.de/Ardumower-GPS-RTK-Kits-GNSS)).

WARNING:

This RTK mower project is still in EXPERIMENTAL state! This is a prototype (not more) to explore RTK GPS, to find out if it could be a solution for some backyards (or even some more), to get experiences with this technology, and to finally build a more complete software with it.





Contents

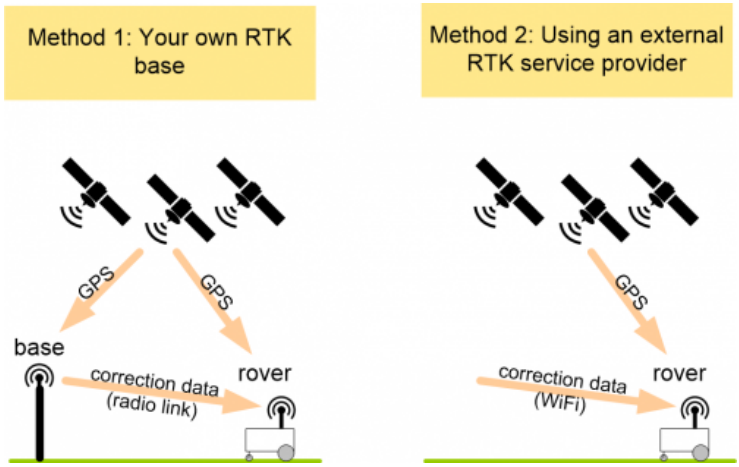
Videos (Demos/Tutorials)

Click below to watch demo and tutorial videos to get an idea what you can do with this RTK system already:

- Promotion: Ardumower 'mowing with a heart'. For those you love. (https://www.youtube.com/watch?v=SU-_ZQzKm3E)
- Intro: Waypoints, Mowing, Docking using cm-precise RTK (https://www.youtube.com/watch?v=1zGeI8IJIyk)
- Demo: Path planning and mowing demo video (showing cm-precise RTK mowing) (https://www.youtube.com/watch?v=yDcmS5zdj90)
- Demo: Docking demo video (showing cm-precise RTK in docking station) (https://www.youtube.com/watch?v=03seYUKiJcc)
- Test: Dynamic obstacle avoidance test (using ultrasonic sensor) (https://www.youtube.com/watch?v=2nr--MbOj6I)
- Test: Testing RTK fix robustness (testing RTK fix robustness near walls, buildings) (https://www.youtube.com/watch?v=_RQcHd0ii0U)
- Test: Single GPS receiver test using Internet-based NTRIP client (SAPOS service) (https://www.youtube.com/watch?v=zBvncTbOVj4)
- Test: Challenging environment test - measurement & visualization of float solution error (https://www.youtube.com/watch?v=Ak0iOOUb1XY)
- Tutorial: How to use the app video (German with English subtitles) (https://youtu.be/fHSolQ5oQfA)
- Podcast: Talk between Markus and Alexander about Ardumower RTK (German) (https://www.youtube.com/watch?v=QT4dSrSzJAc)

What is RTK and what are the requirements (environment and hardware)

RTK-GPS uses two GPS receivers, one for the reference antenna (base) and one for the robot mower (rover) which both communicate in realtime via radio modules (see image below). The base constantly sends correction data so the rover can compute its cm-precise (relative) position. In the RTK-GPS kit, everything required (receivers, radios, antennas etc.) is included. Also, if you don't want to operate your own RTK base, you can use an external base service via Internet (e.g. like Germany's SAPOS). This will reduce the hardware cost by about a half.



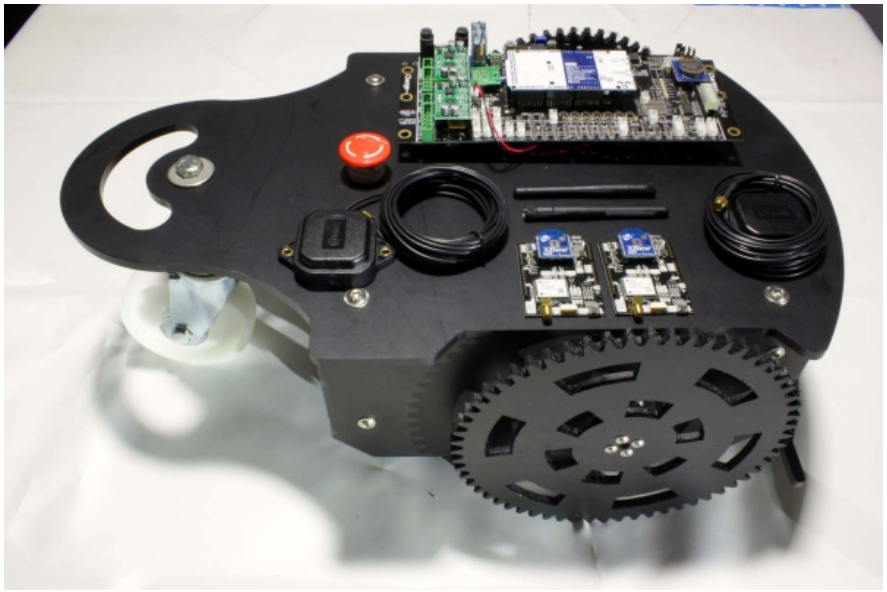
To be able to use RTK-GPS, your robot mower should have a good view to the sky at all locations (see photo below). **RTK-GPS will NOT work under extreme limited sky view, under trees, in buildings etc.**

Some of the environments where we successfully tested RTK GPS:

Environment 'AG' (mostly unobstructed sky view)

Environment 'ML' (partial obstructed sky view due to large trees on the lawn)

These are the hardware requirements to add RTK-GPS to your Ardumower. You can purchase the required hardware from Marotronics (https://www.marotronics.de/index.php?k=7) .



- Ardumower chassis kit using Ardumower motors (incl. odometry) and PCB 1.3 (incl. Adafruit Grand Central M4/Arduino Due and MC33926 motor drivers) (https://www.marotronics.de/Ardumower-Komplett-Set-DIY-Robot-Mower-System-Rasenroboter-zum-selber-bauen-Eigenbau)
- RTK kit (it's recommended to purchase the RTK-GPS modules via Marotronics as you get them pre-configured for the Ardumower there) (https://www.marotronics.de/Ardumower-GPS-RTK-Kits-GNSS)
- Bluetooth 4.0/BLE UART module (CC2540) (https://www.marotronics.de/HM-10-Bluetooth-BLE-BT-40-CC2541-CC2540-fuer-Arduino-iOS-Android-Low-Energy)
- A smartphone (Android/iOS) for configuration of your Ardumower

Assembling the chassis and PCB

Please follow the steps described at the main page (http://wiki.ardumower.de/index.php?title=Hauptseite) for assembling chassis, motors etc. and PCB1.3. After you have assembled the chassis and PCB you can follow the steps below for the RTK functionality.

Significant changes compared to Ardumower's initial firmware (Sunray vs. Azurit)

Ardumower Sunray is an alternative Firmware (experimental) for the Ardumower DIY robotic mower system (https://www.ardumower.de/index.php/en). It **uses RTK GPS to localize cm-precise without a perimeter wire**. It requires Ardumower PCB1.3, Adafruit Grand Central M4(or Arduino Due), Ardumower RTK kit, Bluetooth BLE and a phone (Android/iOS).

- Optimized for PCB 1.3
- Optimized for Adafruit Grand Central M4 (highly recommended) or Arduino Due
- Optimized for RTK
- ⚠ Incomplete (Sunray is 'work in progress') - features like docking, GPS signal-loss detection, obstacle detection and avoidance are experimental and features like mowing zones, improved path planning, are going to be added later...
- ⚠ **Experimental: everything you see in the videos is already working but in early prototype phase (never run your Ardumower unattended with this firmware)!**

Use Azurit Firmware (http://wiki.ardumower.de/index.php) instead if you need a firmware with more complete features for your Ardumower...

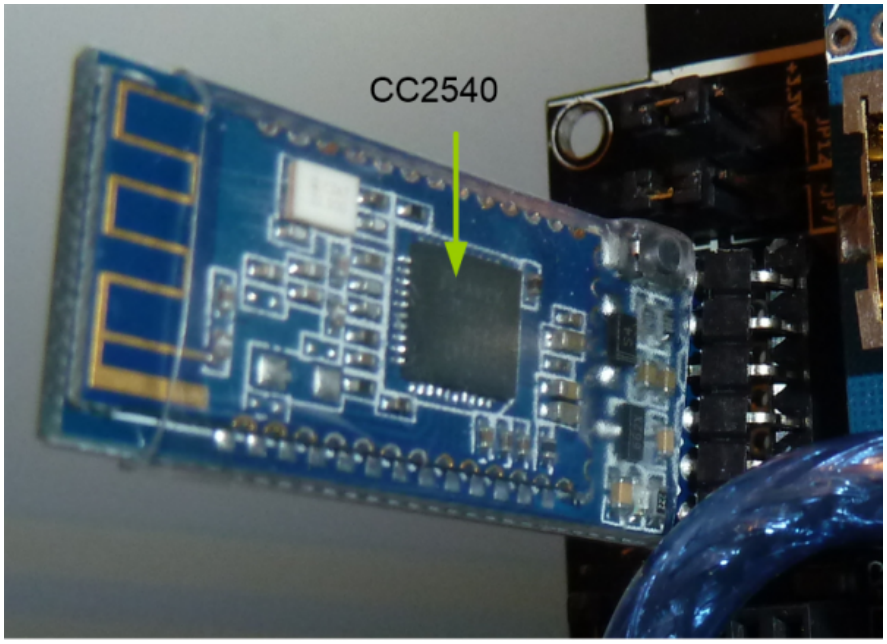
Installation steps

IMPORTANT : Please read ALL **sections below when assembling your Ardumower RTK. Some sections are optional, however most of the sections are important. Sections further to the end are related to troubeshooting and typical errors.**

Bluetooth BLE UART module

1. Install Bluetooth 4.0/BLE module on your Ardumower PCB1.3 (replace any installed Bluetooth 2.0 module).

IMPORTANT: Verify the pinout of your BLE module is matching your Ardumower PCB pinout (shown at the PCB1.3 back side)!



2. Set JP10 (Bluetooth signal level) to 3.3V

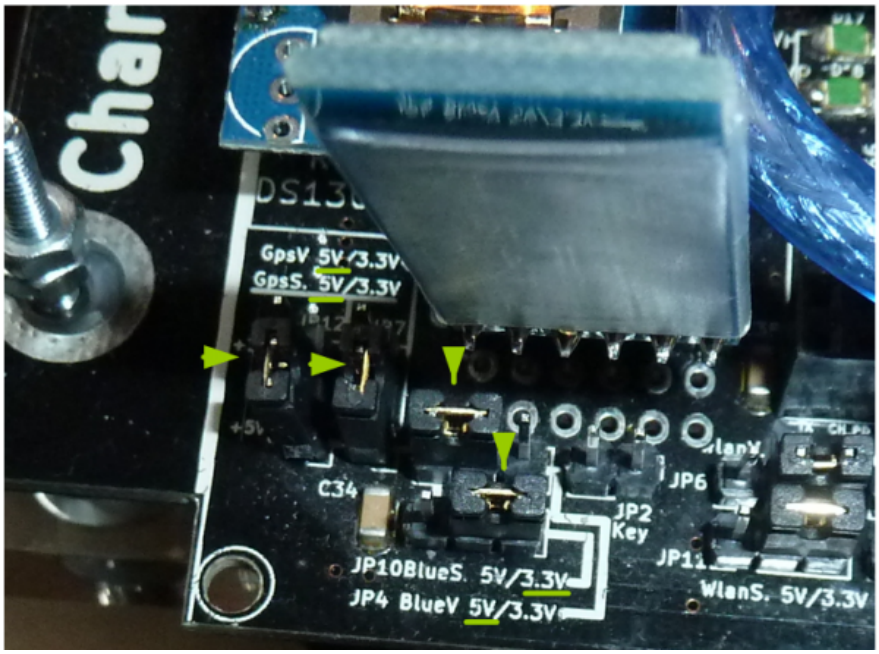
3. Set JP4 (Bluetooth voltage) to 5V

4. Set JP7 (GPS voltage) to 5V

5. Remove any JP12 (GPS signal level) jumpers (please ignore the photo for this jumper - we will not use the level shifter, see section GPS pin fix further below)

6. Set JP6 (WIFI voltage) to 3.3V

7. Set JP11 (WIFI signal level) to 3.V



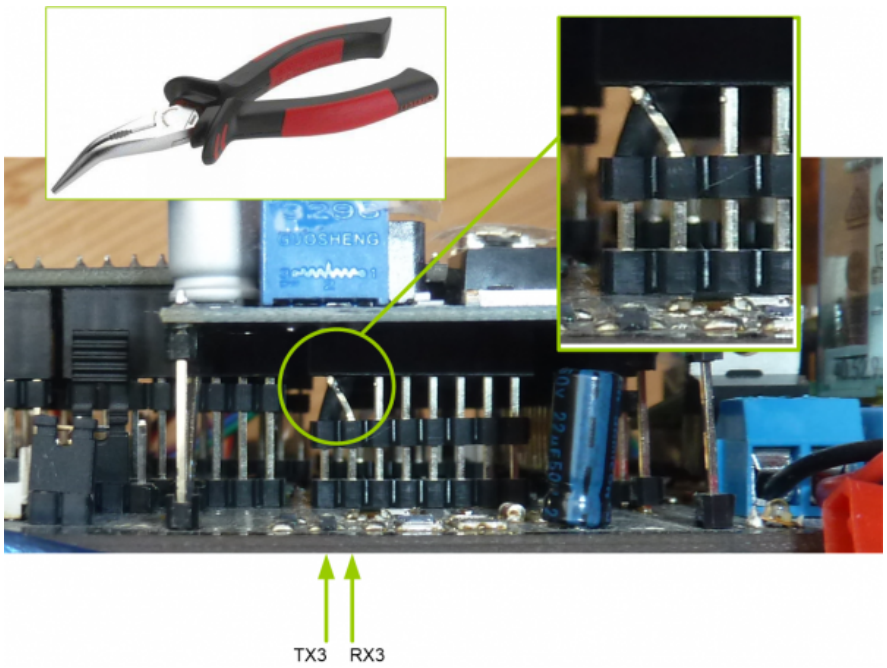
NOTE: If your experience Bluetooth module communication issues, have a look at the GPS RX pin fix (https://wiki.ardumower.de/index.php?title=Ardumower_Sunray#PCB1.3_GPS_pin_fix) and perform the same RX pin fix for the Bluetooth RX pin.

PCB1.3 GPS pin fix

Step 1: Swapping pins

The pins TX3 and RX3 are incorrectly routed on PCB1.3 - Fix it by swapping the TX3 and RX3 pin headers as shown below.

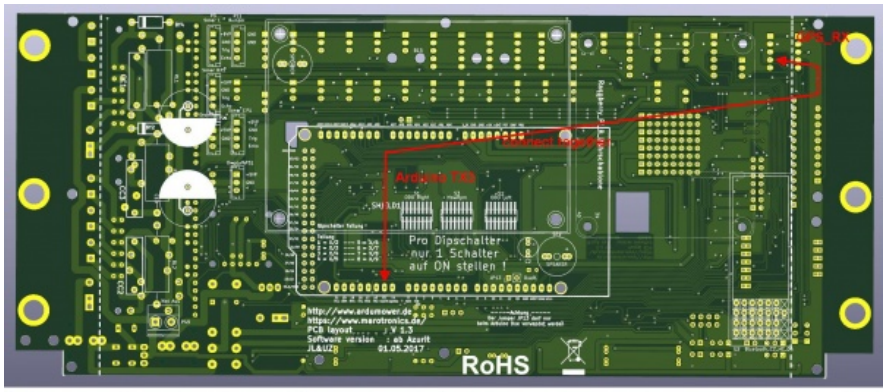
You can see the **fixing process in this video**: https://youtu.be/T-EqU5azCAU?t=140



Step 2: Fixing GPS_RX pin

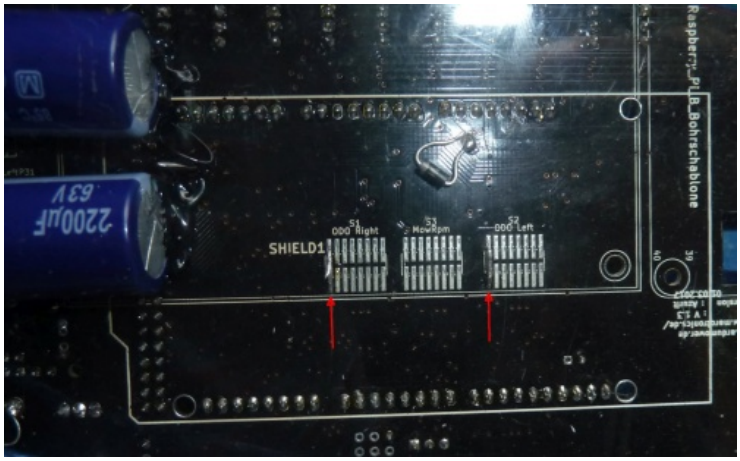
P5 GPS_RX is not working as expected. Fix it with these steps:

1. Directly connect P5 GPS_RX and Arduino TX3 using a wire at the PCB backside as shown below.
2. Remove all jumpers on JP12 Gps_S
3. **IMPORTANT: On the rover GPS module, connect simpleRTK2B IOREF to simpleRTK2B 3V3_OUT (to choose signal voltage level 3.3v).**



PCB1.3 odometry divider

The PCB1.3 odometry divider for the left and right motors should be configured as follows (NOTE: no need to change the mower divider, you can keep your existing mower divider configuration):

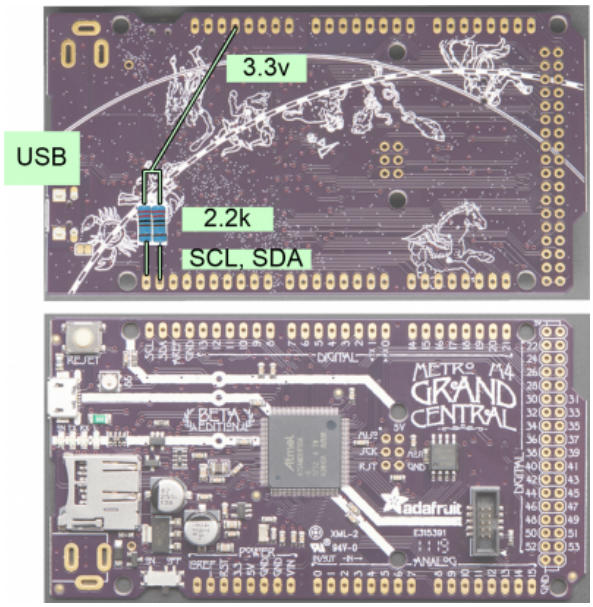


Adafruit Grand Central M4

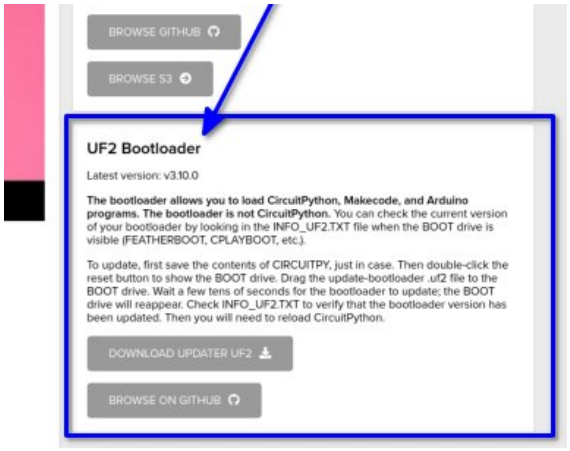
Using the new Adafruit Grand Central M4 (https://www.marotronics.de/Adafruit-Grand-Central-M4-Express-featuring-the-SAMD51) instead of Arduino Due is highly recommended as it has more working memory (RAM) for maps and a floating point unit for faster computations.

Installations steps:

1. **Add 2.2K resistors** (aka 'I2C pull-up') to the Adafruit Grand Central M4 board as shown below. **NOTE: If the pullups are missing, the Ardumower Sunray firmware will hang at boot time and nothing will be displayed on serial console output!**



1. **Disable Ardumower PCB1.3 jumper JP13** (deactivate Arduino Due clone reset circuit).
2. It is highly recommended to **upgrade the bootloader** on the Adafruit Grand Central M4 board. Download the the **latest bootloader file** here (look at the bottom of this link for **.UF2 bootloader** file): https://circuitpython.org/board/grandcentral_m4_express/

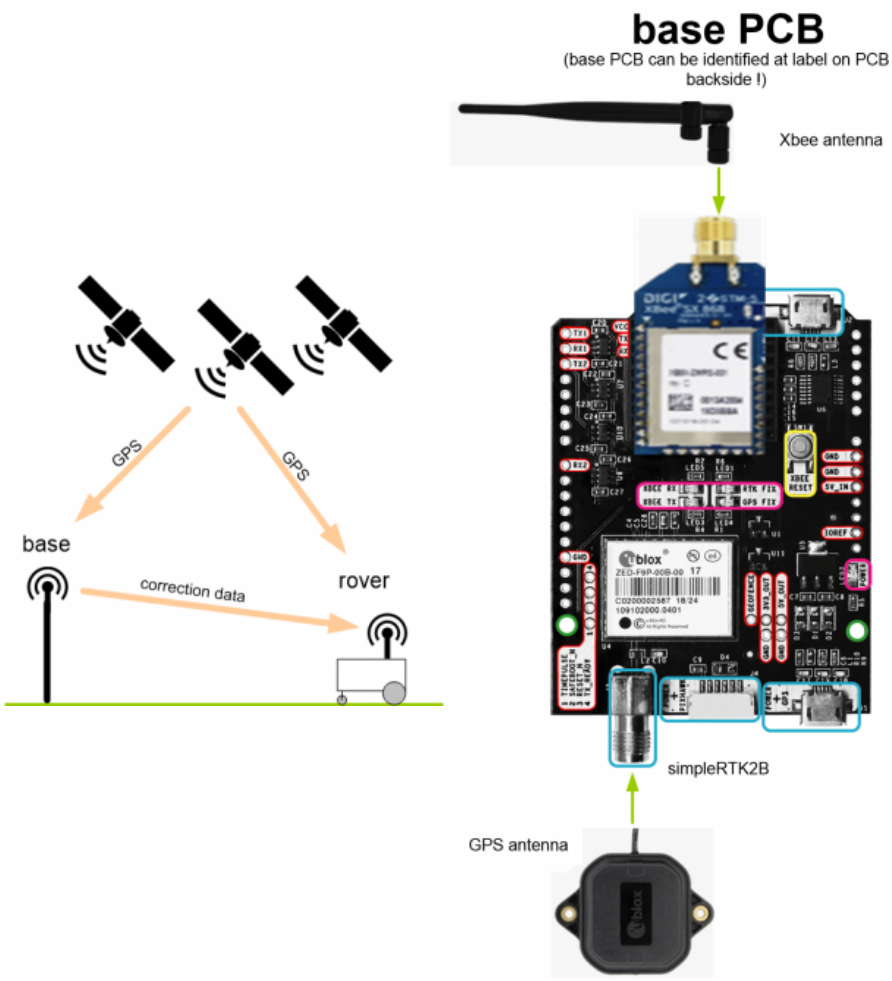


1. **Connect** the Adafruit Grand Central M4 **via USB** to your computer.
2. **Press the RESET button** on the Adafruit Grand Central M4 **twice**, the larger LED on the Adafruit Grand Central will become **GREEN**, and a new drive will appear in Windows Explorer/Mac Finder ('GCMBOOT').
3. **Copy the .UF2 bootloader file** to the Adafruit Grand Central M4 **drive** ('GCMBOOT') - the drive will disappear and after 10 seconds the drive will appear again. The bootloader upgrade has finished (Alternative instructions here: https://learn.adafruit.com/adafruit-grand-central/update-the-uf2-bootloader).
4. Follow the instructions here to add 'Adafruit Grand Central M4' support to the Arduino IDE by installing **both Arduino SAMD boards** and **Adafruit SAMD boards** packages : https://learn.adafruit.com/adafruit-grand-central/setup

RTK base

Method 1: Your own RTK base

This is the **recommended installation method** as it also will give you RTK fix solution results in **cloudy weather conditions**. Your own RTK base should be located **max. 8 km away from your mowing area**. The GPS antenna should have a **clear sky view** and is ideally mounted at a **high (and steady)** position. Using long-range (LR) wireless radio-frequency (RF) modules, the GPS correction signal is transmitted to the robot (it's a one way transmission).



WARNING: Handle your GPS modules with care, it is an expensive piece of hardware. If you have any doubt, or if you are unsure, please ask in the Ardumower forum for help (https://forum.ardumower.de/threads/sunray-firmware-goes-rtk.23690/#post-40042).

1. Make sure you have the simpleRTK2B module marked as '**BASE**' in your hands (look at simpleRTK2B PCB label at backside!)

2. Connect Xbee LongRange dipole antenna

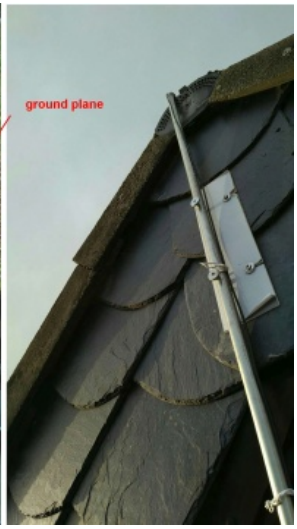
3. Connect GPS multifrequency patch antenna. NOTE: antenna cable is very sensitive, never bend the antenna cable! Minimum bend radius: 5cm!

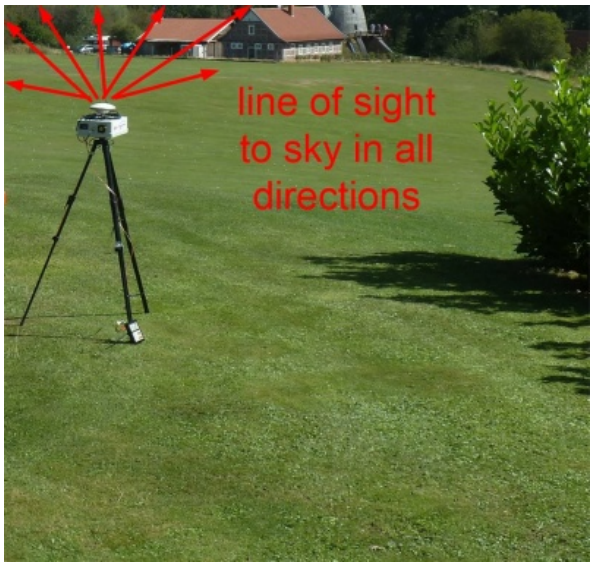
4. Connect a **USB 5v power supply** to the USB port marked as '**POWER+GPS**'

5. Install the GPS base antenna - it should have clear view to the sky in all directions without any obstacles. For best results install GPS **antenna on the roof**. Alternatively, if you have an open area (without trees and other obstacles), you can install the base **antenna on a tripod**.

NOTE: The robot mower will get and save all position coordinates **relative** to the base antenna (East, North) - do not move the base antenna after recording the virtual perimeter with the phone app.

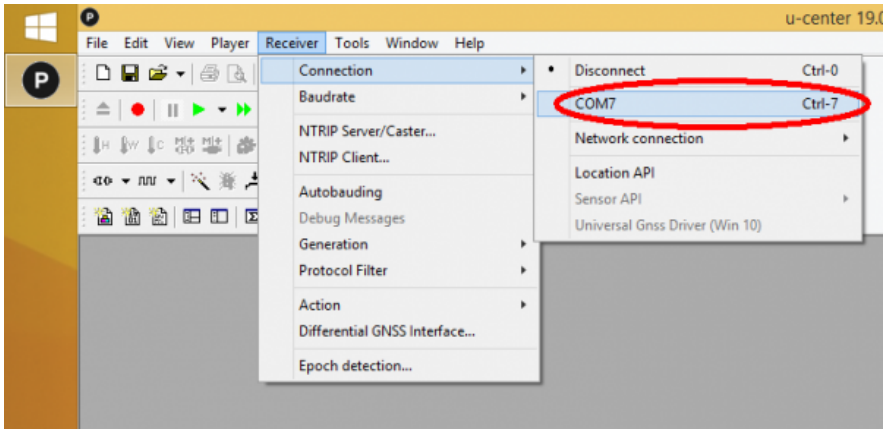
6. Improving position solution **robustness**: for robust position solutions (**FIX**), you will need to **install a (conductive) ground plane (10x10cm, make it round if possible)** for the patch antenna. Install the patch antenna on top of it like shown below. This will give you most robust position results.



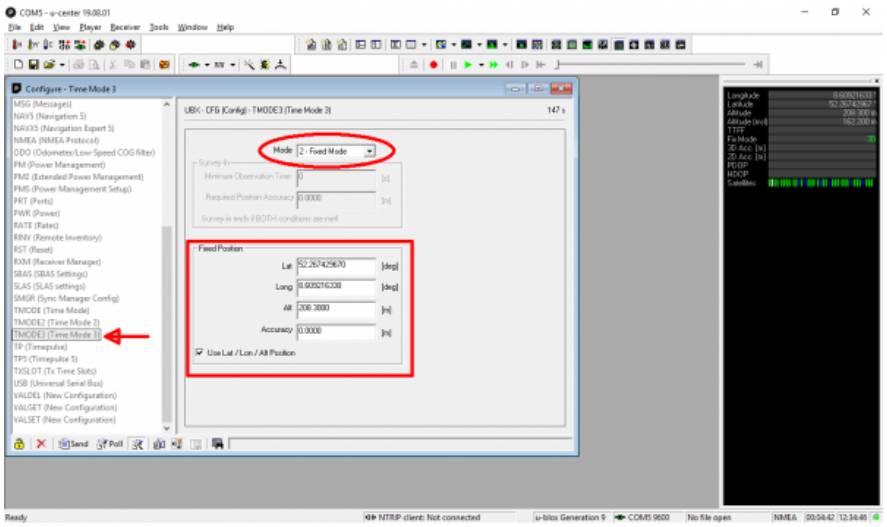


7. Download ublox u-Center and start it: https://www.u-blox.com/en/product/u-center

8. Choose 'Receiver->Connection' and choose your base module COM port.



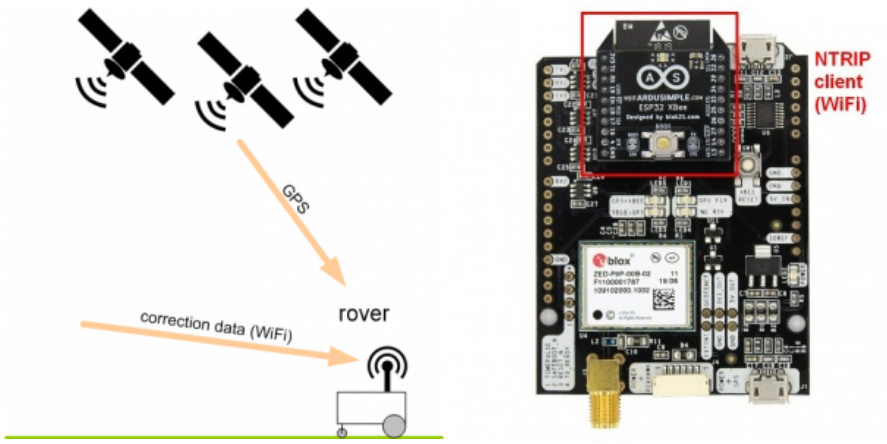
9. Choose 'View->Configuration View'. Choose configuration message '**TMOD3(Time mode 3)**' and choose Mode '**2 - Fixed Mode**'. Enter your base coordinates as shown in the image and click on 'Send'. Your base should get a '**3D**' position solution (verify this!). NOTE: You can find out your precise bases coordinates using the '**Survey-In**' mode which will take several hours to get down to a precise position. NOTE: You can run the survey-in and compare the GPS solution coordinates (latitude and longitude) from hour to hour. If they do not change anymore, your base coordinates are precise.



10. Do not forget to save configuration. From the u-Center menu, choose 'View->Configuration', choose configuration message 'CFG (Configuration)' and click on 'Send' to make the configuration in the base persistent when the rover module is powered off.

Method 2: Using an RTK external base service (Internet-based)

This section describes how to use an **external Internet-based correction service** (NTRIP, e.g. SAPOS in Germany (https://www.sapos.de/), SWEPOS in Sweden, ASG-EUPOS in Poland, and others) instead of your own base station. You can reduce cost with this method because you don't need an RTK base PCB. Instead you will require the WiFi NTRIP Master module for your rover PCB from Marotronics. Follow these steps for the rover PCB:

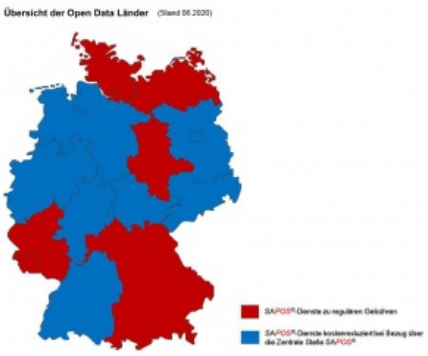


1. Instead of the XBee module **install the WiFi NTRIP Master module** on your rover PCB as shown in above photo.

2. Use your **smartphone or laptop to connect to the WiFi network that the module created**, with name “ESP_XBee_XXXXXX” where XXXXXX is a random number.

3. Go to your **browser** and type the following address “192.168.4.1”, a web interface will appear.

4. Configure your **preferred NTRIP service provider** (**host, port, mountpoint, username, password**), and **through which WiFi network should it connect to internet**. Example NTRIP mount points (Germany SAPOS service generating virtual reference station):

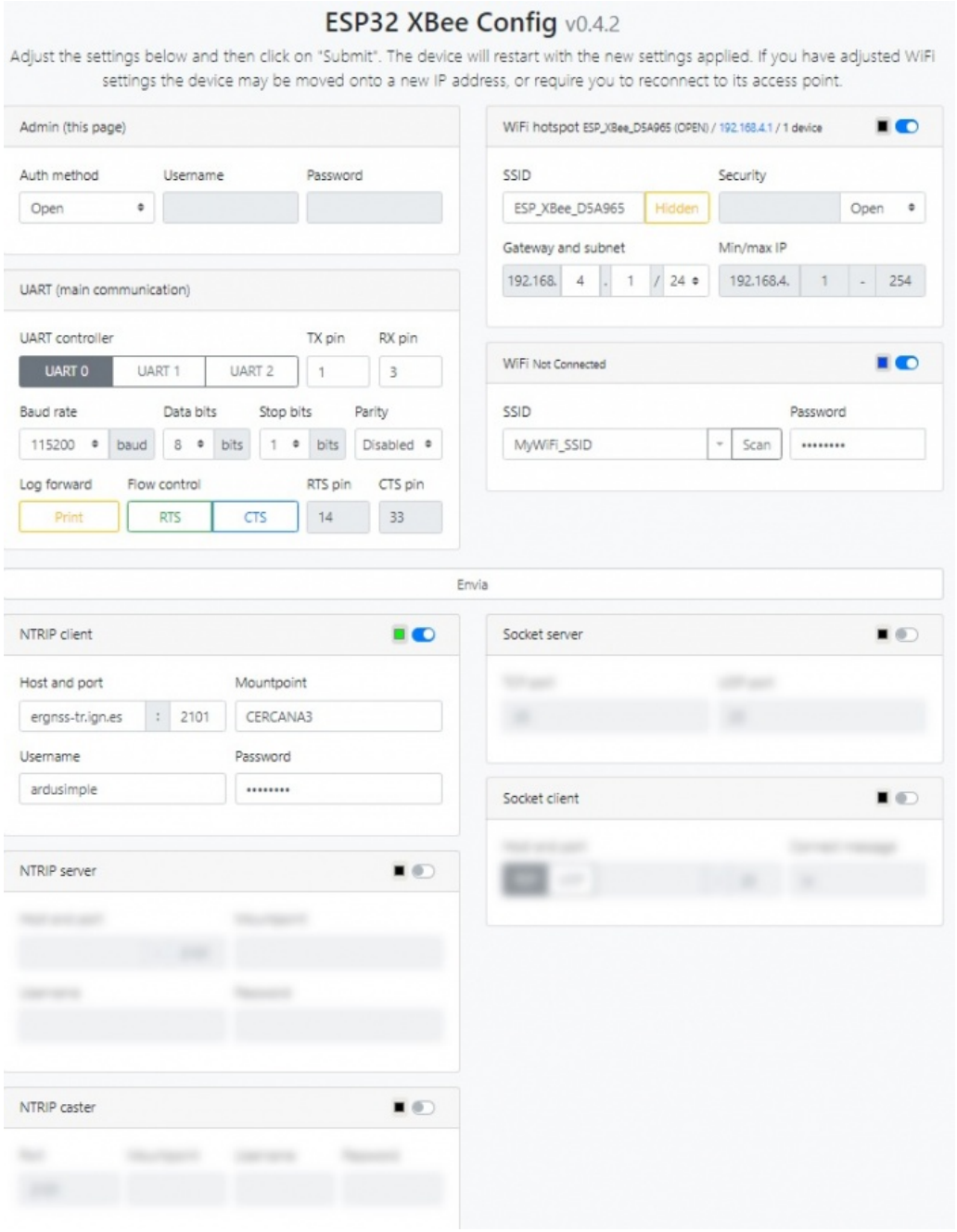



```
Nordrhein Westfalen (SAPOS HEPS): VRS_3_4G_NW
Niedersachsen       (SAPOS HEPS): VRS_3_2G_NI
Berlin              (SAPOS HEPS): VRS_3_2G_BE
Baden Württemberg   (SAPOS HEPS): VRS_3_3G_BW
```

Additionally, you can find out more NTRIP casters here:

- http://www.epncb.oma.be/_networkdata/stationmaps.php
- https://igs.bkg.bund.de/dataandproducts/streams

5. Use UART0 and 115200 baud for the connection to the ublox GPS receiver (rover).



6. Save configuration and reset the system. From now on, every time the WiFi router you configured is in range, the WiFi NTRIP Master will connect autonomously and provide RTK corrections to your rover PCB (If you ever experience any problems and are unable to connect to the NTRIP master device, you can hold the NTRIP master BOOT button for 5 seconds and the ESP32 will be reset to its default configuration). **Verify that your XBee-Wifi-module is successfully connected to the Internet by typing the configured XBee IP address in your browser!**

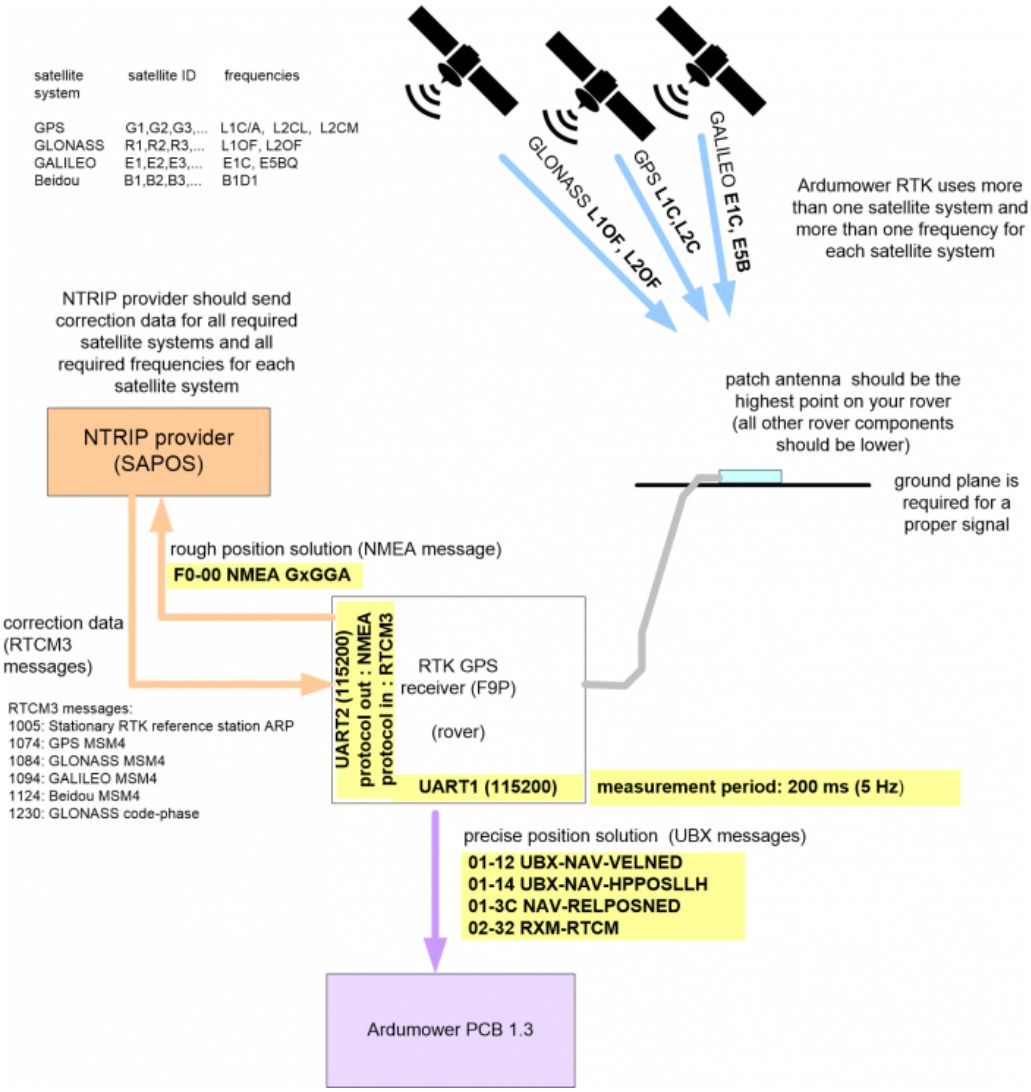
7. Connect the rover PCB via USB to your PC, and make sure **NMEA protocol out is activated for UART2 out at 115'200bps** (**configuration view-> message 'PRT (Ports)'**). Also make sure **NMEA GGA message is active with rate 60 on UART2** (**configuration view->message 'MSG (Messages)'->F0-00 NMEA GxGGA**). Some NTRIP service providers need this NMEA message to compute a virtual base station (VRS) based on the initial estimated GPS fix position. **Verify that the** LED GPS-XBEE **starts to blink which means the GPS receiver is sending the (rough) GPS position to the XBee module!**

8. Finally, verify the **LED 'XBEE-GPS' is blinking** (the rover receives correction data) and the correction age (seconds) shown near the fix solution in the phone app is not increasing. If it does NOT work:

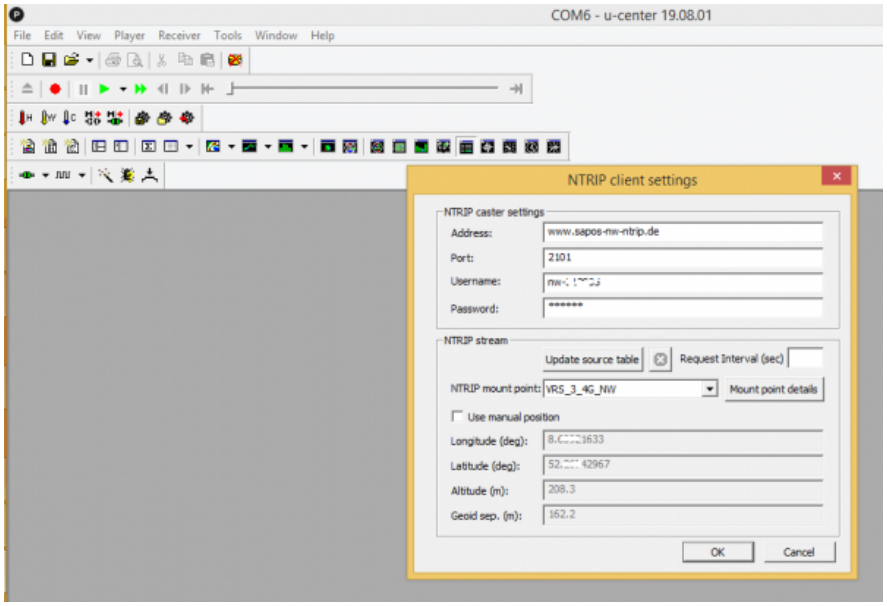
- Verify you have properly configured the rover module (see further below)
- Verify your NTRIP client connection data via ucenter (see further below)
- Activate NTRIP module console output (log forward print), connect GPS rover module via the 2nd USB port (near the NTRIP module) to your PC and start Arduino IDE serial console to monitor the console output

9. If your NTRIP base antenna position is not constant, you have to **switch to position source mode 'absolute' in the App** (see section App for more details).

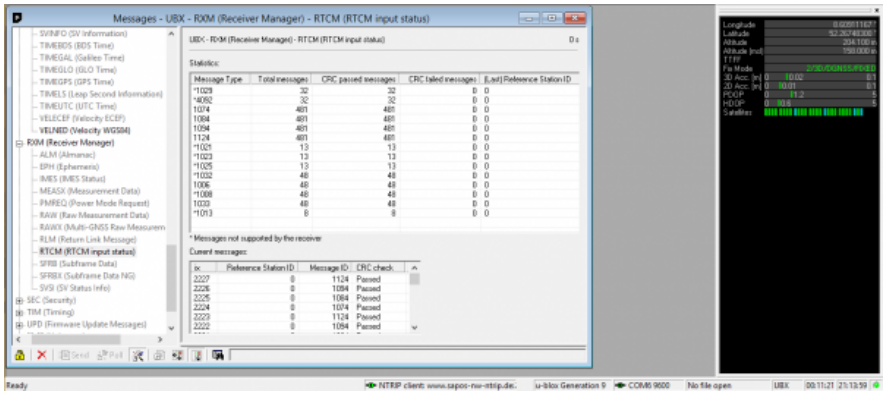
How can I find out if my NTRIP provider (e.g. SAPOS) properly works and supports the required correction messages



You can verify the received correction messages (RTCM3) for the individual satellite systems (GPS, GLONASS, etc.) via ublox uCenter. Start the NTRIP client via 'Receiver->NTRIP client...'



...and then display the received RTCM3 messages via 'View->Messages View->UBX->RXM->RTCM':



These are the **RTCM3.3** messages you should see and may see (* means not supported by F9P receivers , --> means this message should be activated when using your own F9P RTK base station):

```
   1001: L1-only RTK observables
   1002: Extended L1-only RTK observables
   1003: Compact L1&L2 observables
   1004: Extended L1&L2 observables
```

```
--> 1005: Stationary RTK reference station ARP
   1006: Stationary RTK reference station ARP with height
   1007: Antenna descriptor
   *1008: Antenna descriptor and serial number
```

```
   1009: L1-only GLONASS observables
   1010: Extended L1-only GLONASS observables
   1011: GLONASS basic RTK L1&L2
   1012: GLONASS extended RTK L1&L2
   *1013: System parameters
   *1019: GPS ephemeris data
   *1020: GLONASS ephemeris data
   *1021: Helmert/Abridged Molodenski Transformation Parameters
   *1023: Residuals, Ellipoidal Grid Representation
   *1025: Projection Parameters, Projection Types other than Lambert Conic Conformal
   *1032: Physical Reference Station Position
   1033: Receiver and antenna descriptors
```

```
   *1073: GPS MSM3
   *1083: GLONASS MSM3
   *1093: GALILEO MSM3
   *1123: Beidou MSM3
```

```
--> 1074: GPS MSM4
--> 1084: GLONASS MSM4
--> 1094: GALILEO MSM4
--> 1124: Beidou MSM4
```

```
   1075: GPS MSM5
   1085: GLONASS MSM5
   1095: GALILEO MSM5
   1125: Beidou MSM5
```

```
   1077: GPS MSM7
   1087: GLONASS MSM7
   1097: GALILEO MSM7
   1127: Beidou MSM7
```

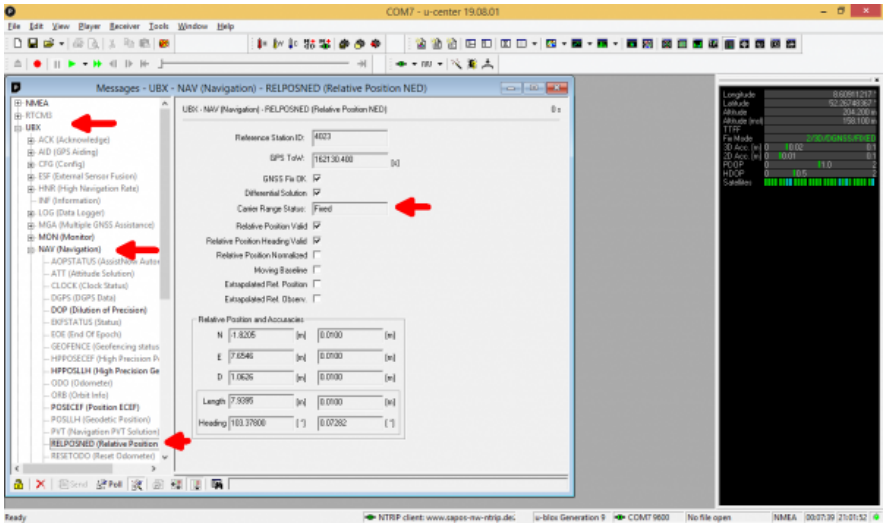
```
--> 1230: GLONASS code-phase (this message could be missing - then 1033 should be received instead!)
```

You can verify the satellite frequencies via 'View->Messages View->UBX->NAV->SIG':

These are the frequencies you should see for each satellite system:

```
   GPS         G1,G2,G3,...   L1C/A
                              L2CL
                              L2CM
   GLONASS     R1,R2,R3,...   L1OF
                              L2OF
   GALILEO     E1,E2,E3,...   E1C
                              E5BQ
   Beidou      B1,B2,B3,...   B1D1
```

And finally, you should see a carrier solution 'float' or 'fix' for a RTK solution:



RTK rover

WARNING: Handle your GPS modules with care, it is an expensive piece of hardware. If you have any doubt, or if you are unsure, please ask in the Ardumower forum for help (https://forum.ardumower.de/threads/sunray-firmware-goes-rtk.23690/#post-40042).

1. Make sure you have the simpleRTK2B module marked as '**ROVER**' in your hands (look at simpleRTK2B PCB label at backside!)

2. Connect XBee LongRange dipole antenna

3. Connect GPS multifrequency patch antenna. NOTE: antenna cable is very sensitive, never bend the antenna cable! Minimum bend radius: 5cm!

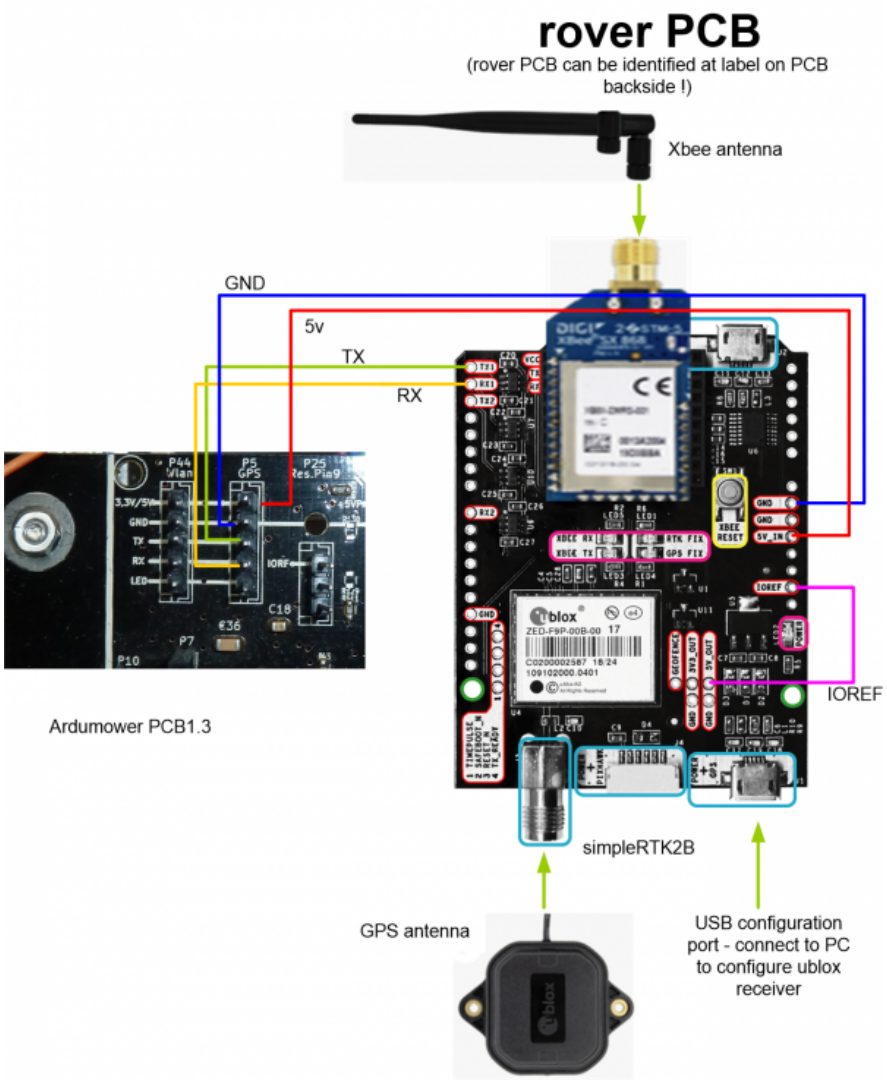
4. Connect PCB1.3_GPS_GND to simpleRTK2B GND

5. Connect PCB1.3_GPS_5V to simpleRTK2B 5V_IN

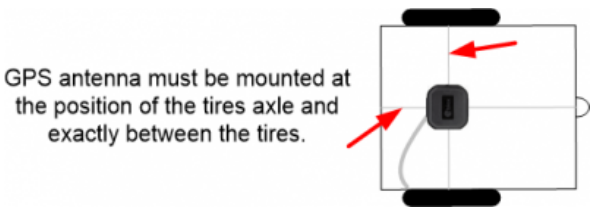
6. Connect PCB1.3_GPS_TX to simpleRTK2B TX1

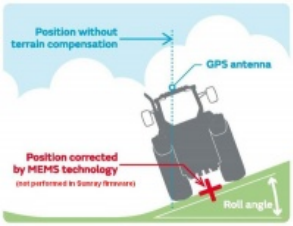
7. Connect PCB1.3_GPS_RX to simpleRTK2B RX1

8. **IMPORTANT: Connect simpleRTK2B IOREF to simpleRTK2B 3V3_OUT (to choose signal voltage level 3.3v)** (ignore the photo for IOREF connection)



9. Install XBee antenna and GPS antenna on the Ardumower. The **GPS antenna must be mounted at the point where the robot rotates around (aka the 'control point')**. For a 2 differential wheel robot, this position is at the tire axle and between both tires. Do not mount the GPS antenna too high because when there's slope the higher position of the antenna is not the same as the position of the robot (see example with slope below):





10. Improving position solution **robustness**: for robust position solutions (**FIX**), you will need to **install a (conductive) ground plane (10x10cm, make it round if possible)** for the patch antenna. Place the patch antenna on top of it like shown below. This will get you most robust position results. Note: you do not have to ground the ground plane as the contact to antenna is capacitive.

More details about ground planes for patch antennas can be found in the u-blox GNSS Antennas Application note (UBX-15030289) (https://www.u-blox.com/sites/default/files/products/documents/GNSS-Antennas_AppNote_%28UBX-15030289%29.pdf#%5B%7B%22num%22%3A67%2C%22gen%22%3A0%7D%2C%7B%22name%22%3A%22XYZ%22%7D%2C51%2C376%2C0%5D) and in ublox Multi-band, high precision GNSS antennas (ANN-MB series) (https://www.u-blox.com/sites/default/files/ANN-MB_DataSheet_%28UBX-18049862%29.pdf).

Rover configuration (messages)

NOTE: below steps for rover configuration using u-center software are no longer necessary - the Sunray firmware will automatically configure your ublox f9p GPS module (rover) when started - please skip this section.

⚠ **WARNING: Only apply the steps below for the ROVER module - not for the BASE module!!** ⚠

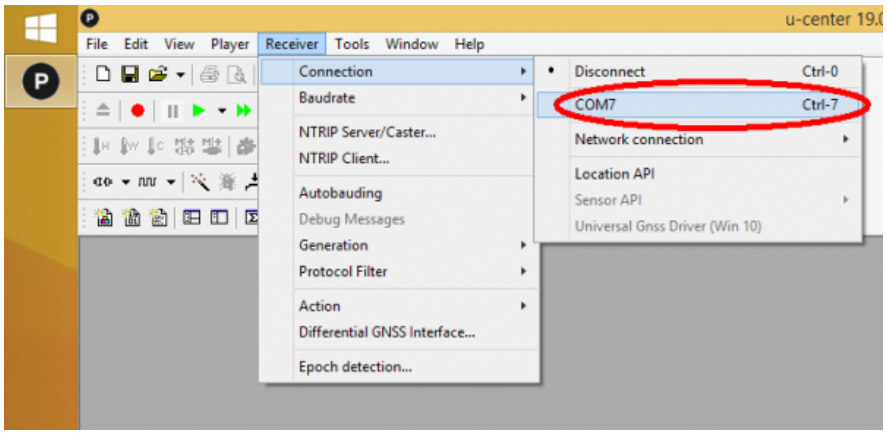
NOTE: If you purchased your RTK-GPS modules at Marotronics, these modules should be pre-configured and you can skip this section.

1. IMPORTANT: **Make sure the Ardumower is turned off!**

2. Connect SimpleRTK **ROVER** module USB port marked as '**POWER+GPS**' to your PC.

3. Download ublox u-Center and start it: https://www.u-blox.com/en/product/u-center

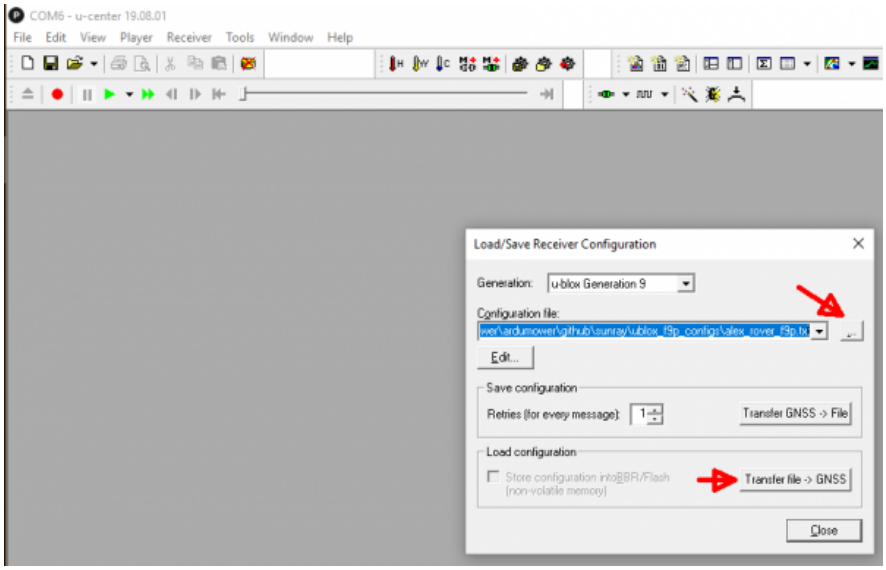
4. Choose 'Receiver->Connection' and choose your rover module COM port.



--Method 1 (Using a configuration file - recommended)--

5. Download the ublox rover configuration file (you can find it in the folder 'ublox_f9p_configs'): https://github.com/Ardumower/Sunray/archive/master.zip

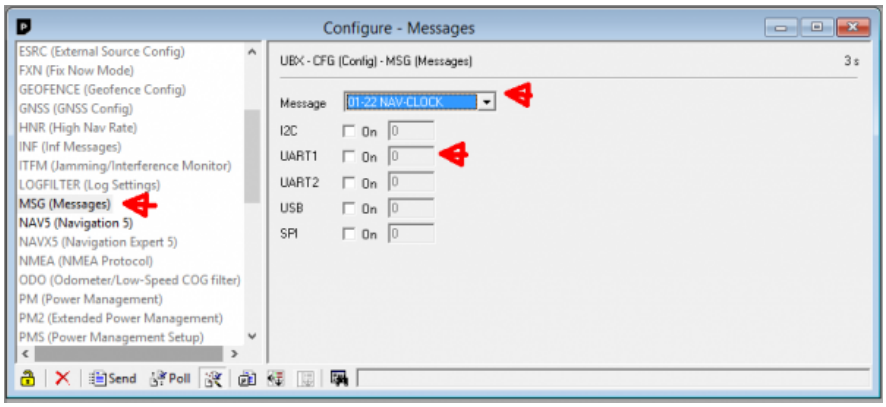
6. Using ublox u-Center, upload the configuration file to your ublox receiver (rover). Choose 'Tools->Receiver Configuration...', choose the config file and then transfer it to the GPS receiver.



After your ublox receiver has been configured, go to point 9 to permanenlty save the configuration in the GPS receiver.

--Method 2 (Without configuration file)--

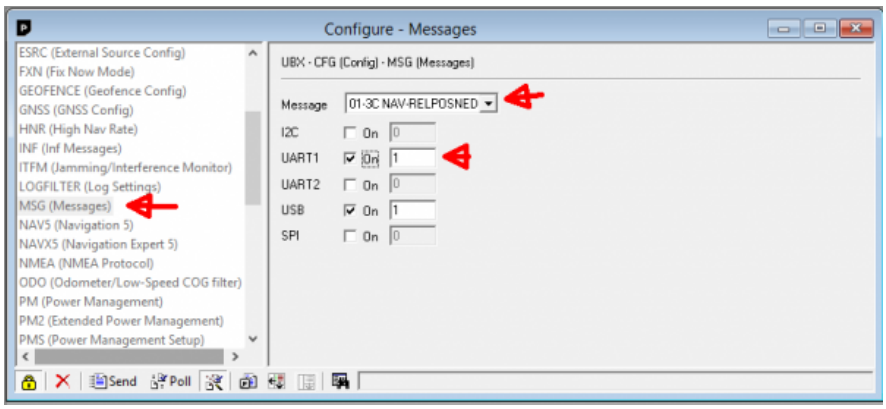
5. In this step we want to **turn off all broadcast messages** except one. Choose 'View->Configuration View'. Choose configuration message 'MSG (Messages)' and select one message after the other in the list (0A-37 MON-HW3, 0A-09 MON-HW, ..., etc.). For each message, make sure the selected message is turned off for **UART1** and **UART2**. Example for message '01-22 NAV-CLOCK' that has been deactivated for **UART1**:



Repeat this step for all messages in the listbox and turn off all messages for **UART1** and **UART2**.

6. Activate the following messages and rates for **UART1** and USB:

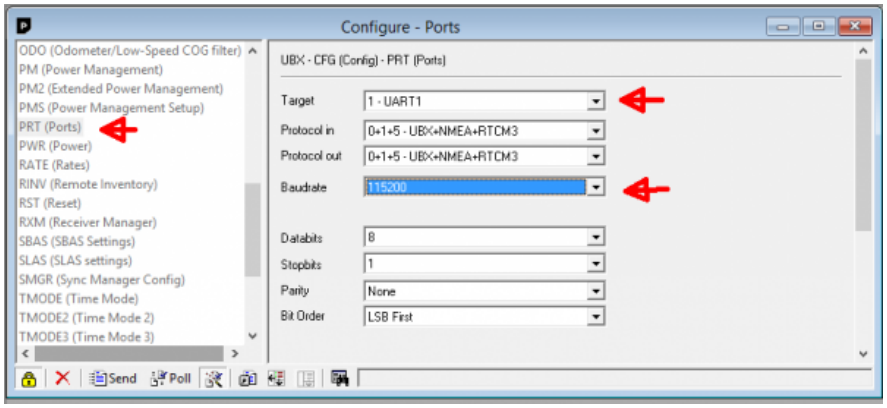
```
01-07 UBX-NAV-PVT          10
01-12 UBX-NAV-VELNED       1
01-14 UBX-NAV-HPPOSLLH     1
01-3C NAV-RELPOSNED        1
01-43 NAV-SIG              10
02-32 RXM-RTCM             5
```



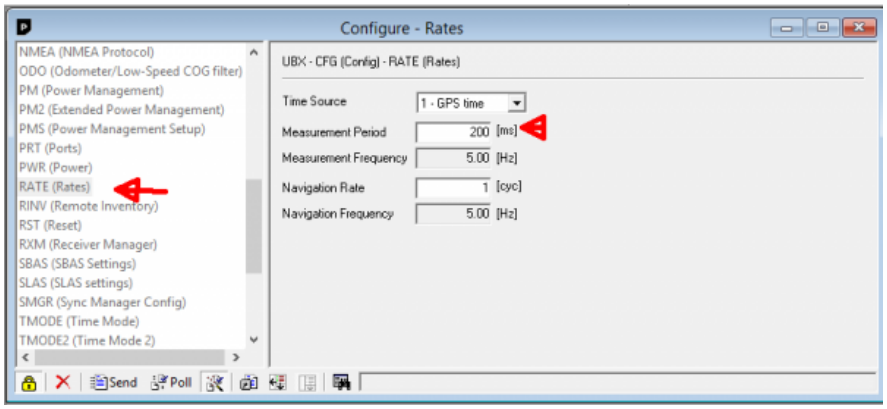
7. Activate the following message and rate for **UART1** and **UART2** and USB:

```
F0-00 F0-00 NMEA GxGGA    60
```

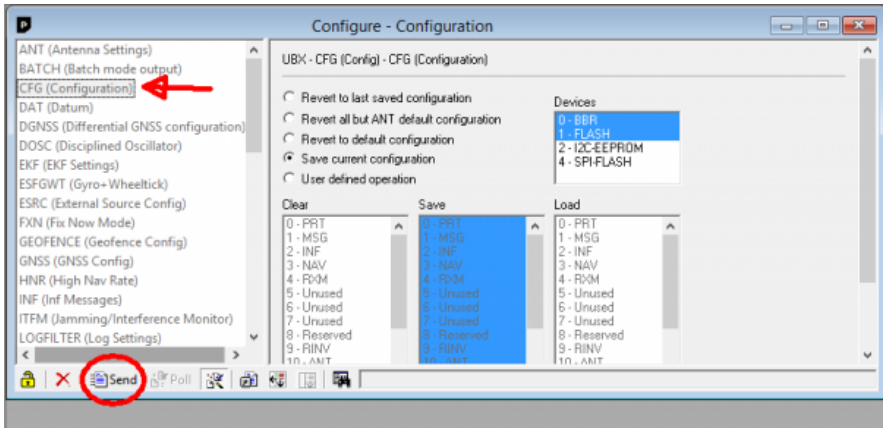
8. Choose configuration message 'PRT (Ports)', choose 'UART1', and set baudrate to 115200 for UART1:



9. Choose configuration message 'RATE (Rates)' and set measurement period to 200ms (5 Hz):



10. From the u-Center menu, choose 'View->Configuration', choose configuration message 'CFG (Configuration)' and click on 'Send' to make the configuration in the rover persistent when the rover module is powered off.



11. Verify that the configuration is actually persistent in the rover module - disconnect the rover module and reconnect. Then go through all previous steps and verify that the configuration is still present.

12. IMPORTANT: **Disconnect USB cable from rover module!**

Download, Arduino Code, Firmware

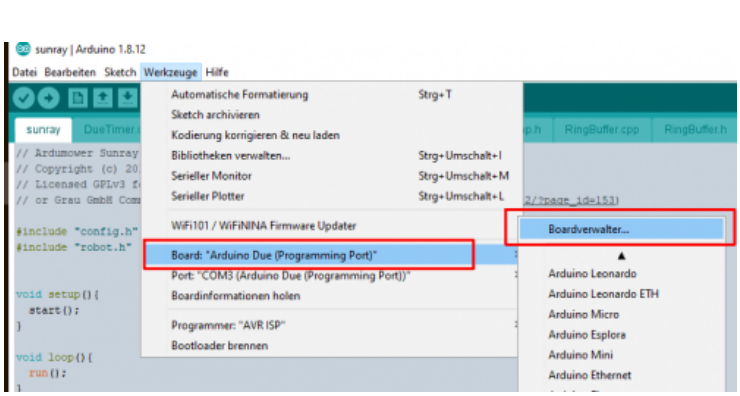
In this section you will upload the Arduino code ('Sunray Firmware') to your Ardumower.

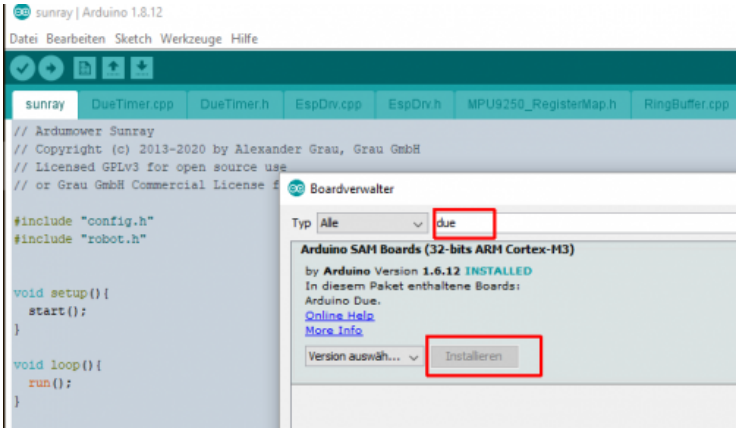
1. **Download** and start Arduino IDE: https://www.arduino.cc/en/Main/Software

2. **Download** Ardumower Sunray Firmware and unzip it: https://github.com/Ardumower/Sunray/archive/master.zip

3. **Open** the Arduino sketch 'sunray\sunray.ino'.

4.1 For **Arduino Due**: In Arduino IDE, choose 'Tools->Board->Manage' and enter 'Due'. **Install** the 'Arduino SAM Boards'

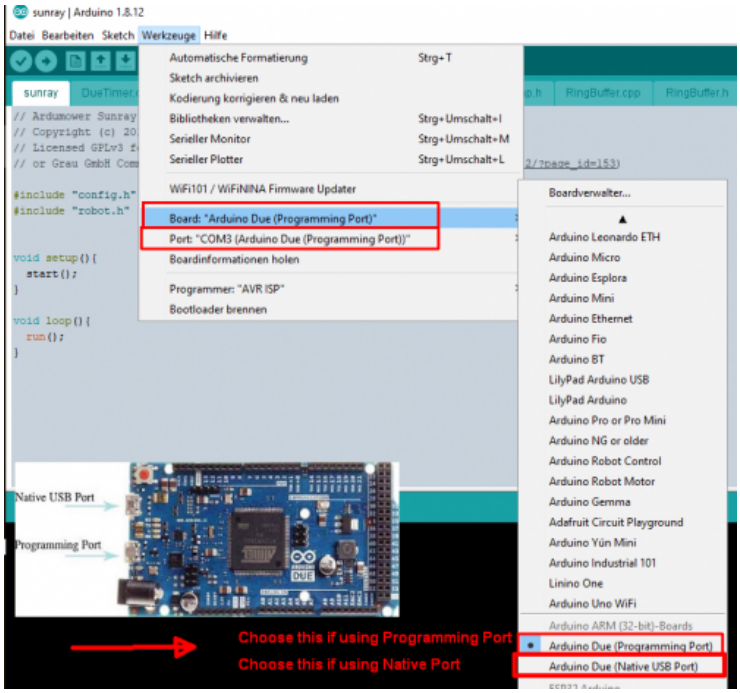


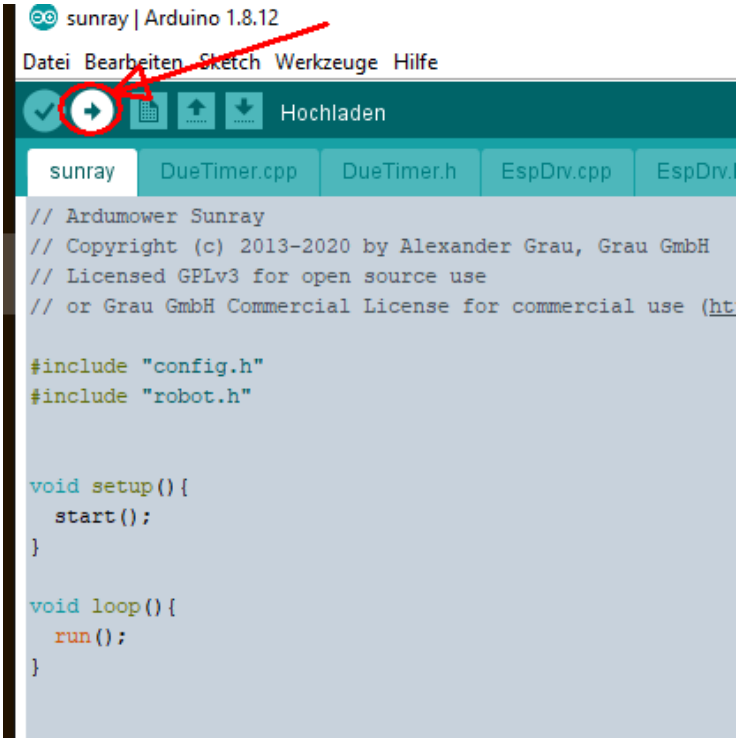


4.2 For **Adafruit Grand Central M4**: Follow the instructions here to add 'Adafruit Grand Central M4' support to the Arduino IDE by installing **both Arduino SAMD boards** and **Adafruit SAMD boards** packages : https://learn.adafruit.com/adafruit-grand-central/setup

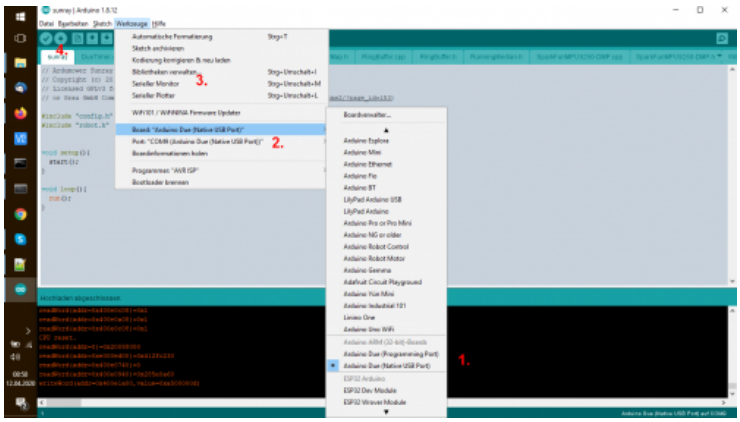
5. **Start** your Ardumower (via the PCB1.3 button P20).

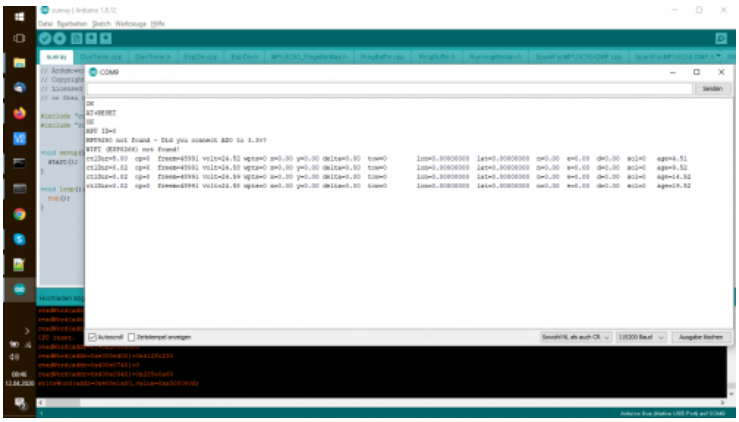
6. **Connect Arduino Due USB native port** (or Adafruit USB port) to your Computer's USB port. In the Arduino IDE, choose the correct board and port and **Upload** the sketch to your Arduino Due/Adafruit Grand Central on the Ardumower PCB1.3. After a short while you should hear a 'beep'. Ardumower is now ready for your commands!





7. If you experience problems (e.g. **phone cannot connect to your Bluetooth module**), it is recommended to **view the serial console** of the Ardumower. Connect the Arduino Due via the USB port labeled 'native' to your PC. Choose board 'Arduino Due native USB port' in the Arduino IDE and choose the available Due native COM port. Then choose 'serial monitor' to see the console. Finally choose upload. After uploading, the output on the console should appear and should look like below. The lines 'OK', 'AT+RESET', 'OK' indicate that the Bluetooth module was found. Also, if your Bluetooth module is not listed in the App,ensure that you give the App Bluetooth permissions.





Phone App

NOTE: You can use the Sunray App using the free license with limited features. After trying out the free version, you can **purchase a Sunray App basic/pro license here**: http://grauonline.de/cms2/?page_id=3170. (NOTE: I have been working full-time one year on the firmware and App. Please support my work by purchasing a license. Thank you! :-))

Click here to download the **Sunray App Quickstart manual** here: https://drive.google.com/file/d/1NNrUEm2_amfMAjGY7ShcYtixtUgWGnyJ/view?usp=sharing

In this section you will download the App to your phone (Android or iOS) which is used to configure the maps for your mower.

Using the phone app, you can:

- manually steer the mower
- record the virtual perimeter and exclusions
- calculate the waypoints for the mower
- start/stop the mower

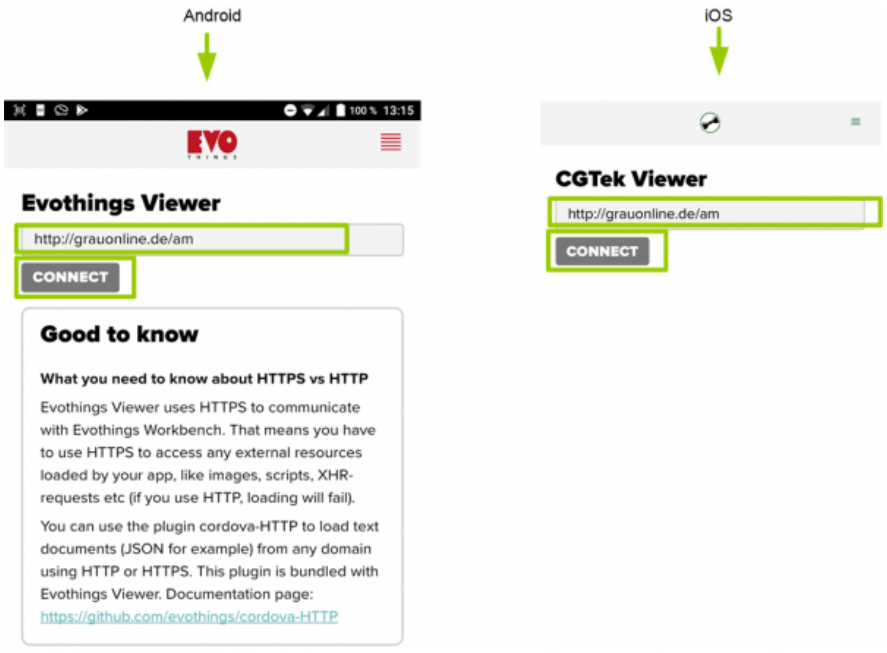
NOTE: all maps will be stored on the phone - however maps can be shared and then imported on other devices.

NOTE: The robot mower will work with position coordinates **relative** to the base antenna (East, North) - do not move the base antenna after recording the virtual perimeter.

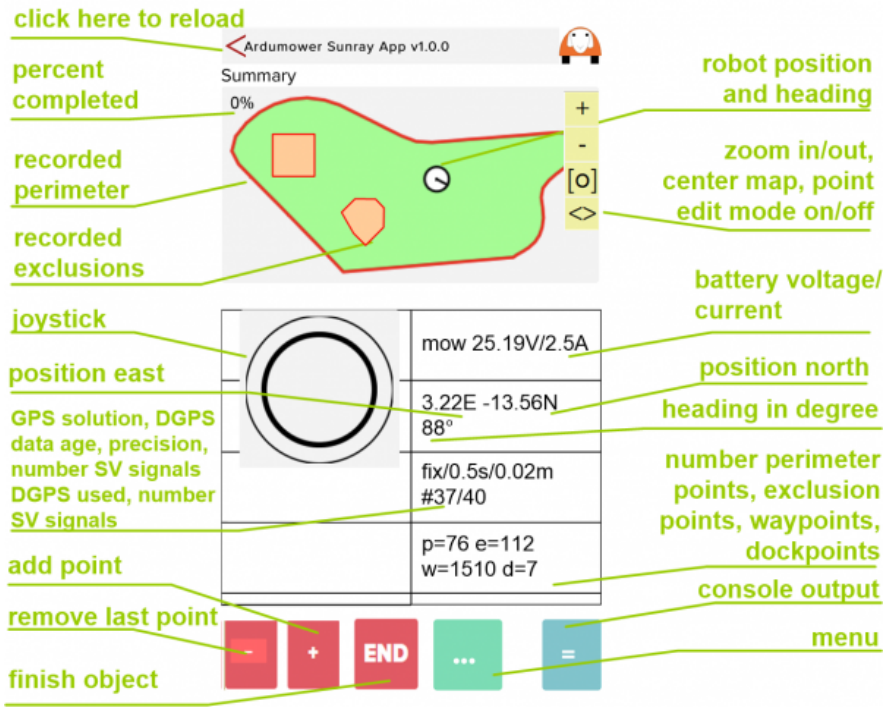
1. Download Viewer App:

```
For Android, download Evothings Viewer: https://play.google.com/store/apps/details?id=com.evothings.evothingsviewer
For iOS, download CGTek Viewer: https://apps.apple.com/de/app/cgtek-viewer/id1135118284
```

2. Start App and enter the connection URL as show below and press 'Connect':



3. The App should start as shown below:



Position solution display (Sol/Age)

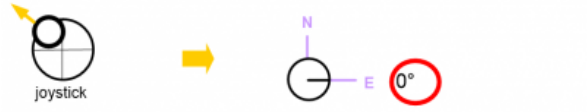
invalid	no DGPS solution was found
float	DGPS solution was found but it is ambiguous and therefore not precise (average error ~20cm).
fix	DGPS solution was found and it is cm-precise - position is tracked in realtime (RTK)
age	The age (in seconds) of the DGPS correction data sent from base

Odometry test

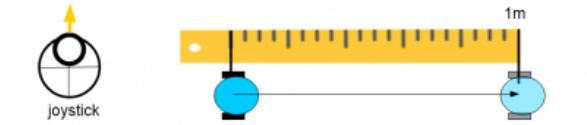
Before connecting GPS, **verify the odometry** of your motors! If you are **unable to smoothly steer the robot via the App manually**, this will probably fix it!

Both, the robot's motor odometry and GPS-RTK are used to localize the robot. Therefore, it is **important to verify that the odometry is working correctly as shown below**. Start the phone app and follow the steps below to verify that your mower odometry is configured correctly. For this test, **make sure that your RTK is turned off (e.g. RTK base module is turned OFF)!**

1. Using the joystick, turn the robot until the app calculated heading is ~0 degree:



2. Using the joystick, manually drive the robot 1m straight on a ruler:



3. Verify that the app calculated distance is also ~1m:

4. Using the joystick, turn the robot so the app calculated heading is ~0 degree.
Then turn the robot with your eyes so that it physically makes a 360 degree turn.

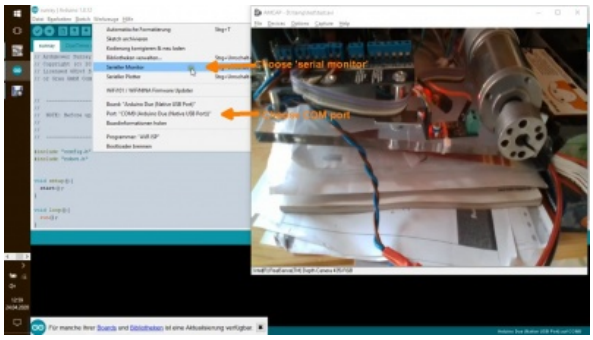
5. Verify that the app calculated heading is again ~0 degree:

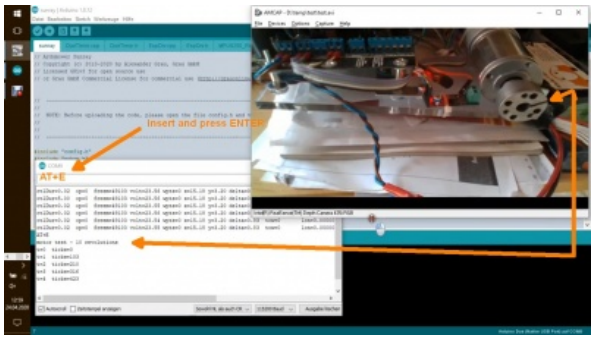
6. If both distance and heading are correctly calculated by the app, the robot's odometry is working correctly.

NOTE: If the distances are not correctly measured by the robot, you can adjust the odometry values in config.h.

Additionally, you can **find out the correct values for your motor** by running the motor test in the Arduino console.

Motor test video link: https://drive.google.com/open?id=1ejT8j1Ioq8bDpk3RmWuki5KqI9K1Jq9h





Finally, the motors should be manually controllable very smoothly as seen in this video: https://youtu.be/fHSolQ5oQfA?t=136

Position source mode

RTK: DGPS can solve the precision problem between a fixed base and a moving rover. However, it **cannot compute absolute GPS coordinates (latitude/longitude) precisely**. To be able to compute absolute GPS coordinates for a moving rover, you have to know the absolute coordinates of the base. Then the rover can add the precise relative measurements to the absolute base coordinate to compute a precise GPS coordinate.

The ublox GPS receiver sends two positions to the Ardumower:

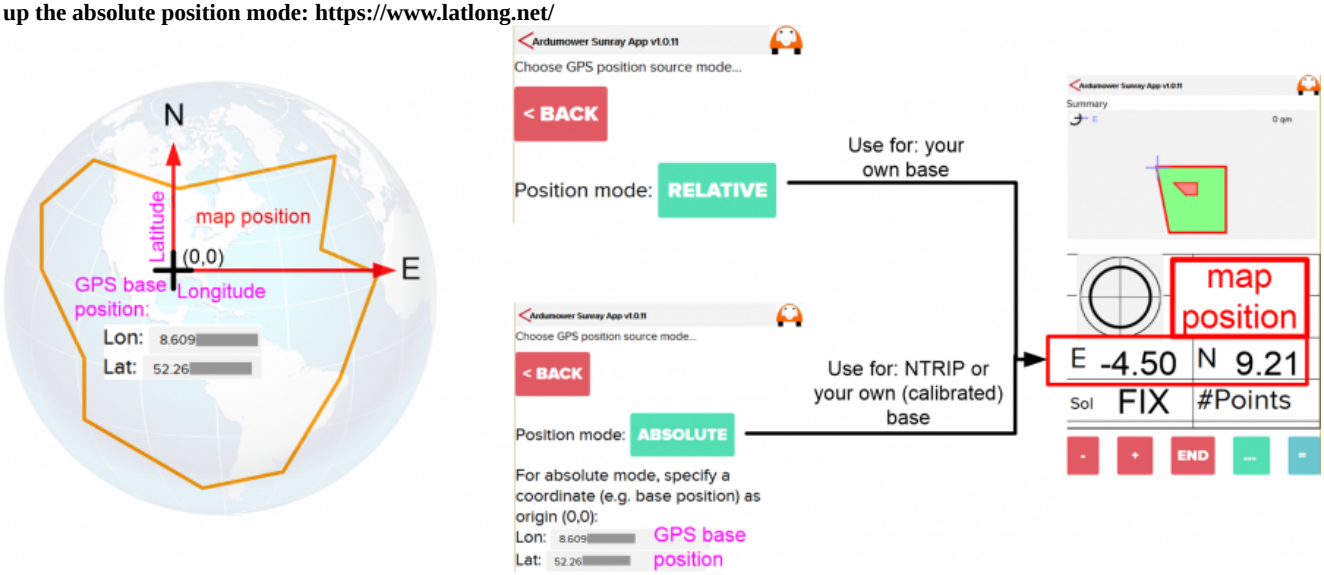
```
a) one base-relative position (east/north) in meters (this is used in relative mode)- because virtual base station
   (VRS) coordinates move each start, this mode cannot be used for SAPOS/VRS
b) one absolute latitude/longitude position (this is used in absolute mode and the base coordinate set in the app is always
   substracted from this to calculate again east/north in meters)
```

To save memory, the rover will always use relative **coordinates** for the map etc. The map origin (0,0) for the maps can be choosen in the App. **WARNING: The relative coordinates cannot be larger than +/-300m. You have to ensure that the map origin (0,0) is not further away than 300m from all recorded points in your map.**

In the App (menu 'Position mode'), you can choose between those two position source modes:

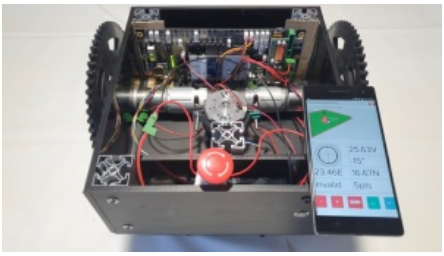
```
relative: the rover coordinates are always relative to the base antenna  (use this when using your own base) - if the base
          moves after a map recording, you have to switch to absolute mode
absolute: the rover coordinates are computed as relative to some specified (e.g. your base antennna or house)
          world coordinate (see image below - use this when using an NTRIP client or for a different base position)
```

Tip: You can use Google Maps to find out (Lon, Lat) coordinates for your location and use them as coordinate (lon,lat) for your base station to set up the absolute position mode: https://www.latlong.net/



Record perimeter and exclusions

Please watch this help video on how to record perimeter and exclusions:



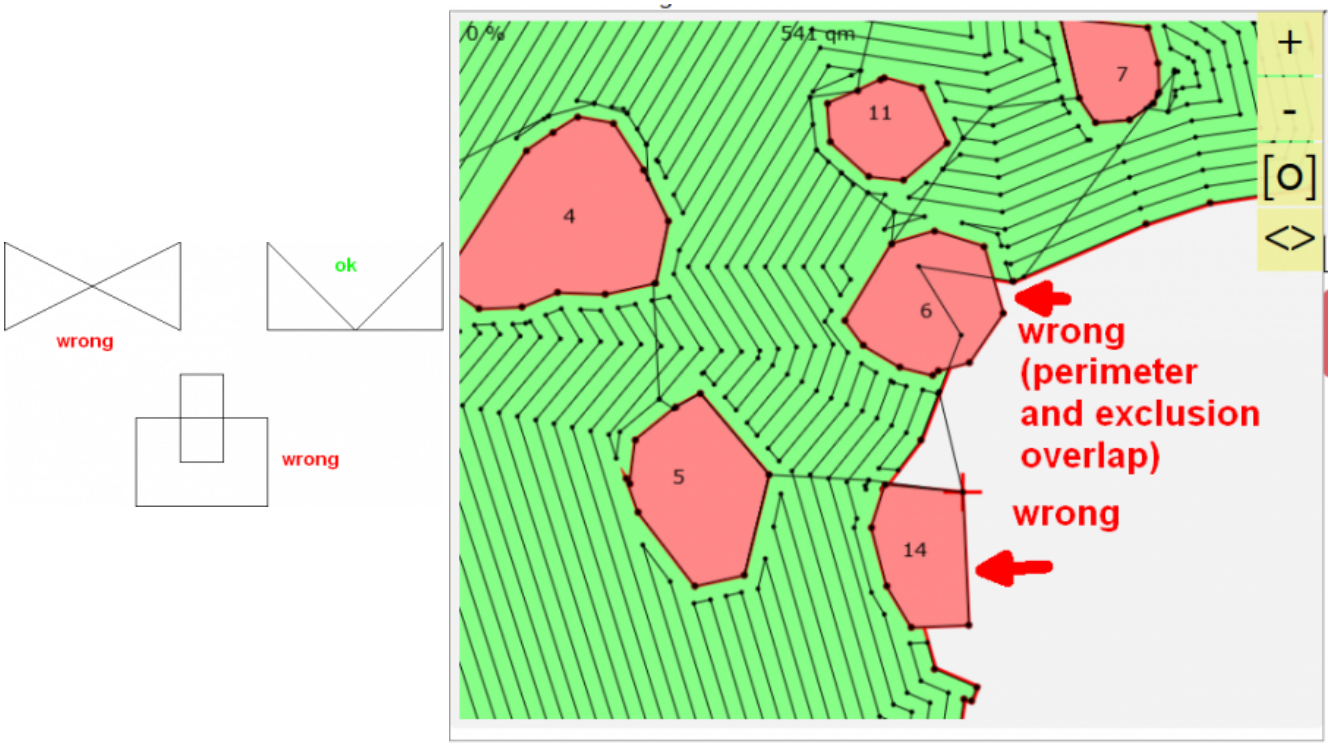
Click here for tutorial video: How to use the app, how to record perimeter and exclusions (German with English subtitles) (https://youtu.be/fHSolQ5oQfA)

Click here for video: How to test GPS precision (https://www.youtube.com/watch?v=OEUQSRzVzwE)

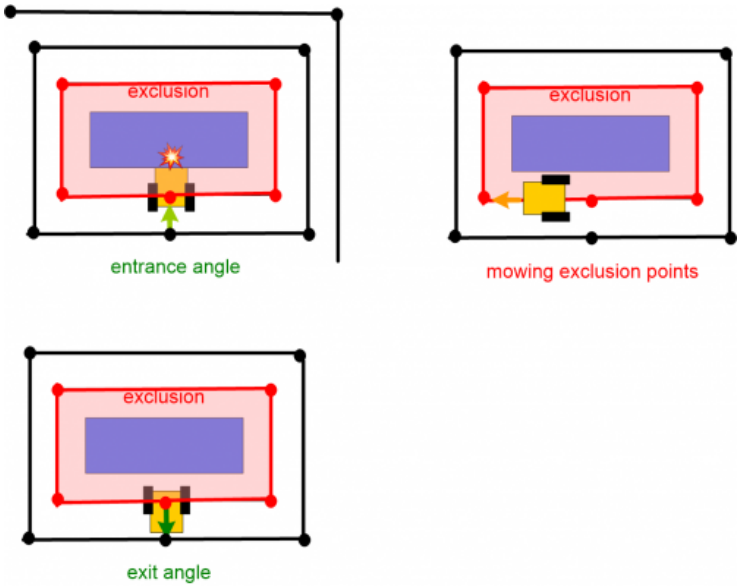
Click here for video: Demonstration of mow pattern (rings and lines), pattern angle and mowing offset (https://www.youtube.com/watch?v=V8658HAVFhs)

When recording perimeter and exclusions make sure that your perimeter polygon and each of your exclusion polygons do not overlap itself and other polygons.

Example of one polygon overlapping itself and one polygon overlapping another polygon (not allowed):



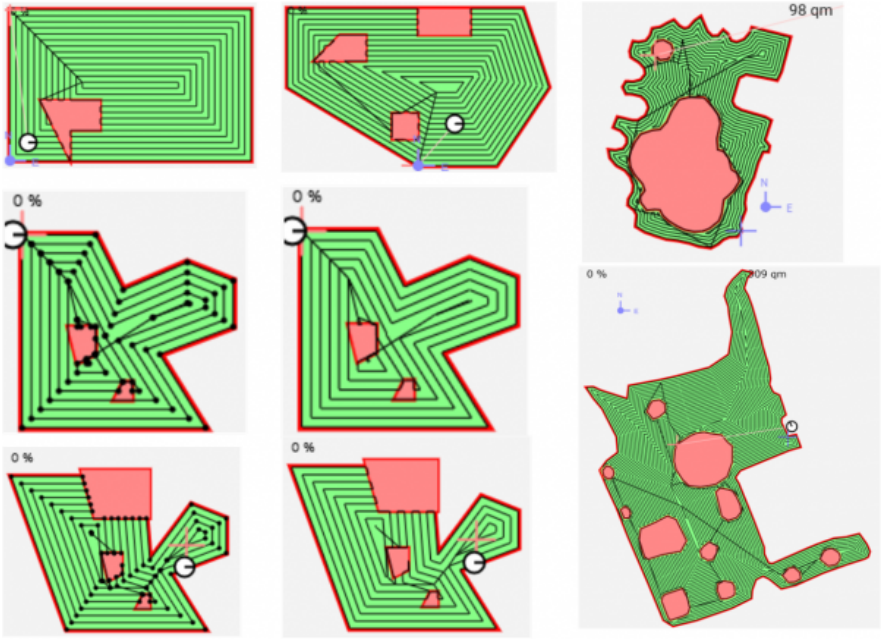
Also, when recording your exclusions, make sure there is enough space around obstacles for entry and exit points where the mower needs to rotate!



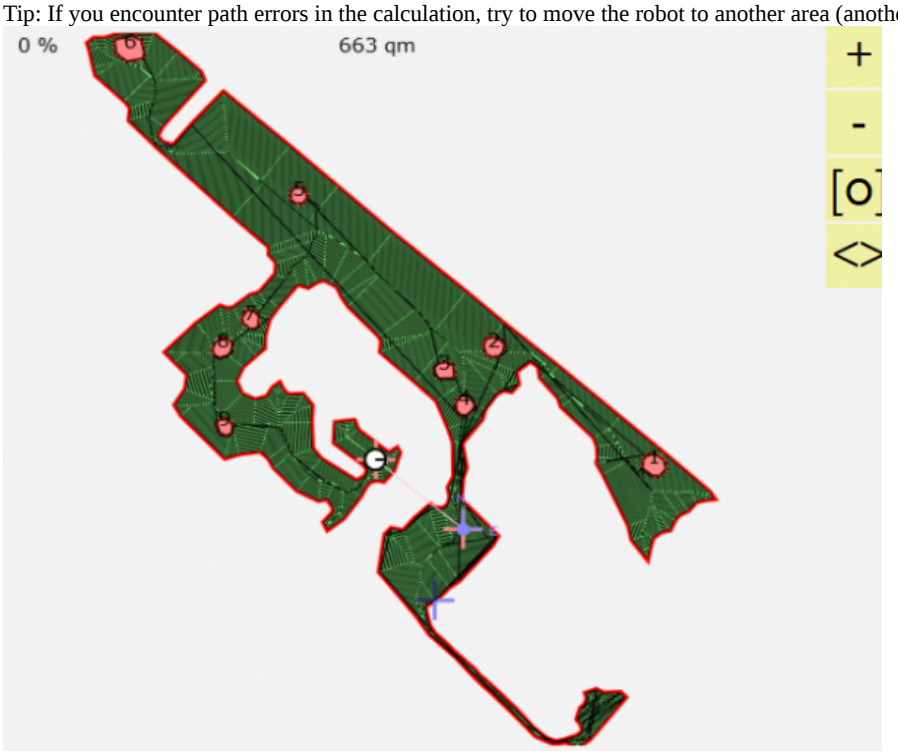
Mowing pattern, pattern angle, mowing offset

Click here for video demonstration of patterns, pattern angle and mowing offset (https://www.youtube.com/watch?v=V8658HAVFhs)

Example maps:

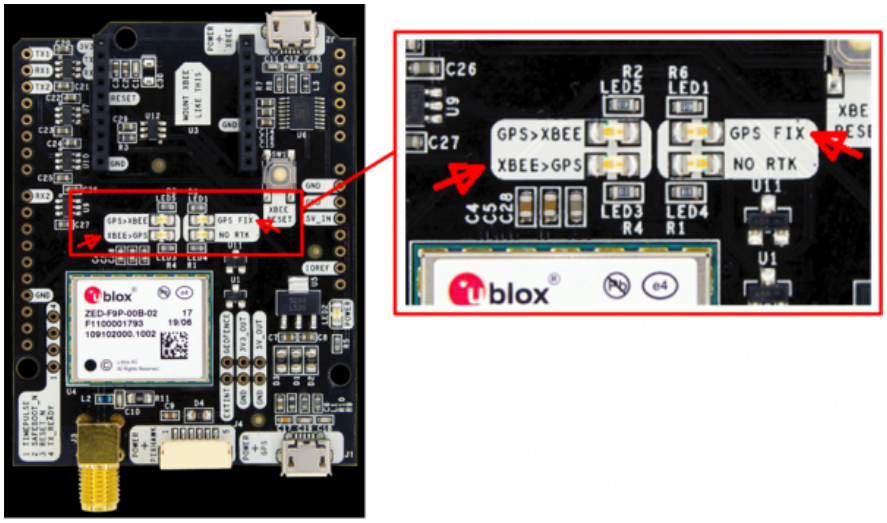


Tip: If you encounter path errors in the calculation, try to move the robot to another area (another position) and then recalculate the waypoints.



RTK GPS test (invalid, float, fix) and FIX robustness and correctness

The base and rover LEDs can be used for trouble-shooting. Verify that the LEDs are acting as described below.



The base and rover LEDs should be as follows:

Base LEDs

GPS>XBEE	should blink - your base module is sending satellite reference data to your rover module (via the XBee module)
XBEE>GPS	should be OFF - your base module should not receive any XBee/reference signal
GPS FIX	should blink - your base module has found a valid GPS signal
NO RTK	should be ON - your base module is not performing RTK (real time kinematic)

Rover LEDs

GPS>XBEE	should be OFF - your rover module should not send any XBee signal
XBEE>GPS	should blink - your rover module is receiving satellite reference data from your base module (via the XBee module)
GPS FIX	should blink - your rover module has found a valid GPS signal
NO RTK	should be OFF - your rover module has found a RTK FLOAT or FIX (is performing real-time kinematic)

Fix robustness

Depending on the robot's location (e.g. near trees), it may take some time to get a RTK FIX solution. Also, it appears this RTK FIX can get lost quickly in the first minutes (e.g. near trees). However, after several minutes running time, the RTK FIX is more robust (even near trees). So, for best position results, let the GPS 'warm-up' some minutes at a location with good sky view.

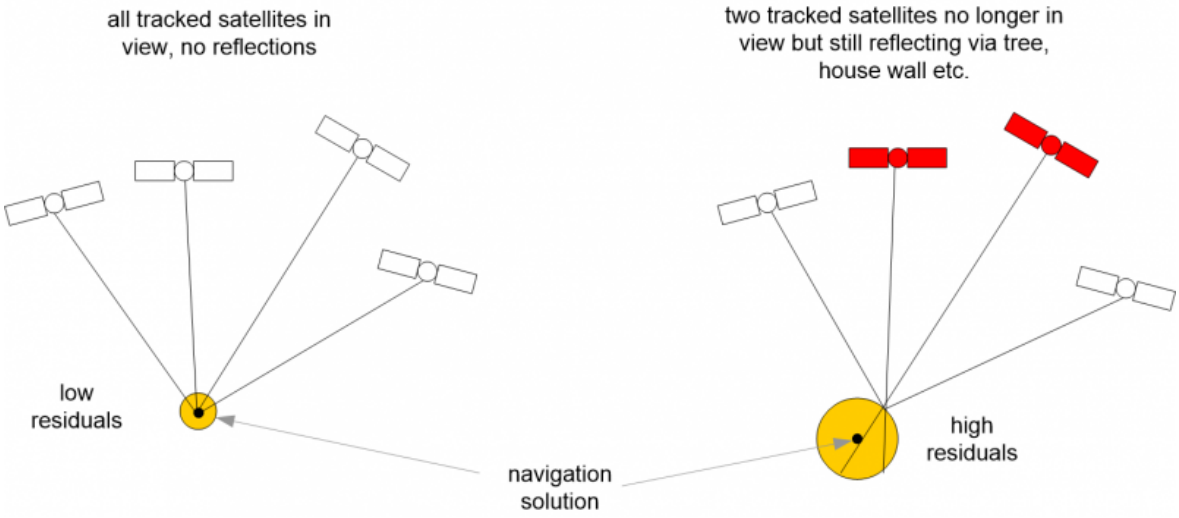
Fix correctness

⚠ NOTE: If you power-on the receiver (mower) at limited sky view, the receiver may get a RTK FIX solution but this FIX may be **incorrect** (and all following data is offset by this incorrect start position!). Therefore it is recommended to always power-on the receiver (mower) at a position with **good sky view** and to always power-on **at the same position**!

RTK float-to-fix recovery and false-fix issues

The described GPS filter below is now configured automatically in the Sunray firmware. Please skip this section.

If you experience **RTK float-to-fix recovery** issues (no fix after timeout), or if you experience (slightly) **false-fix solutions**, the problem might be satellite reflections in the navigation solution:



The solution to this problem is to configure a signal strength filter (dB) like below (to filter out satellite reflections for a navigation solution). It is assumed that reflective signals have a significant lower signal strength than direct satellite signals.

Default navigation input filters settings:

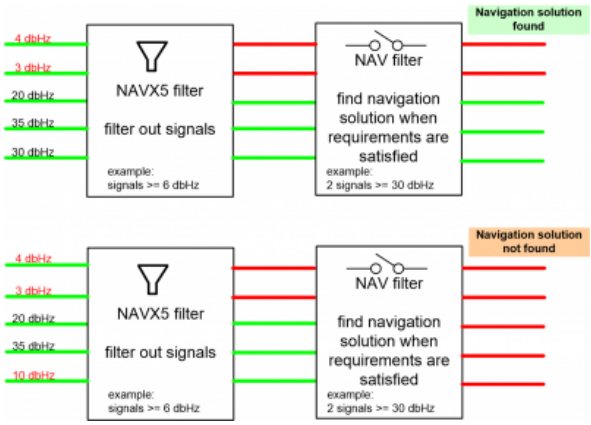
```
Min SV Elevation: 10 [deg]
C/N0 Threshold  : 0  [#SVs]
                  0  [dbHz]
```

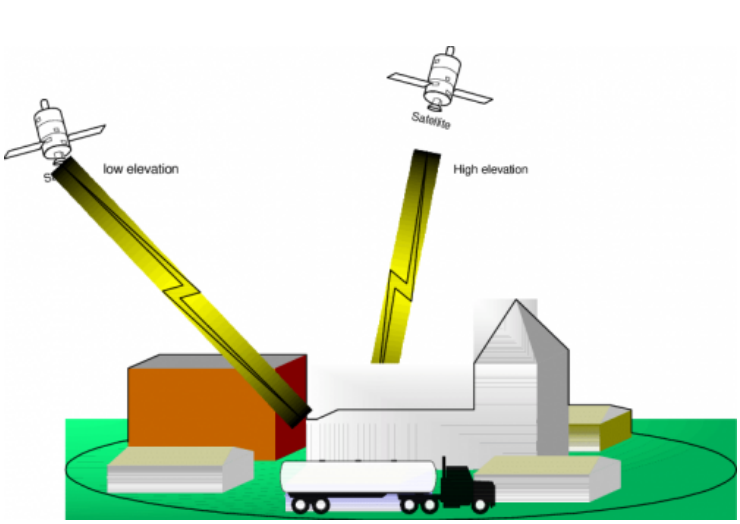
More restrictive navigation input filters settings (this will filter/reduce satellites required for a GPS navigation solution!):

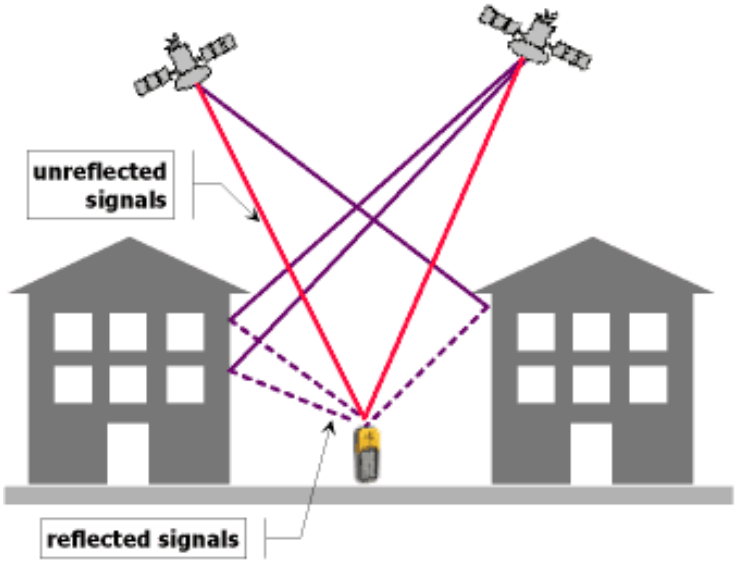
```
Min SV Elevation: 10 [deg]
C/N0 Threshold  : 10 [#SVs]
                  30 [dbHz]
```

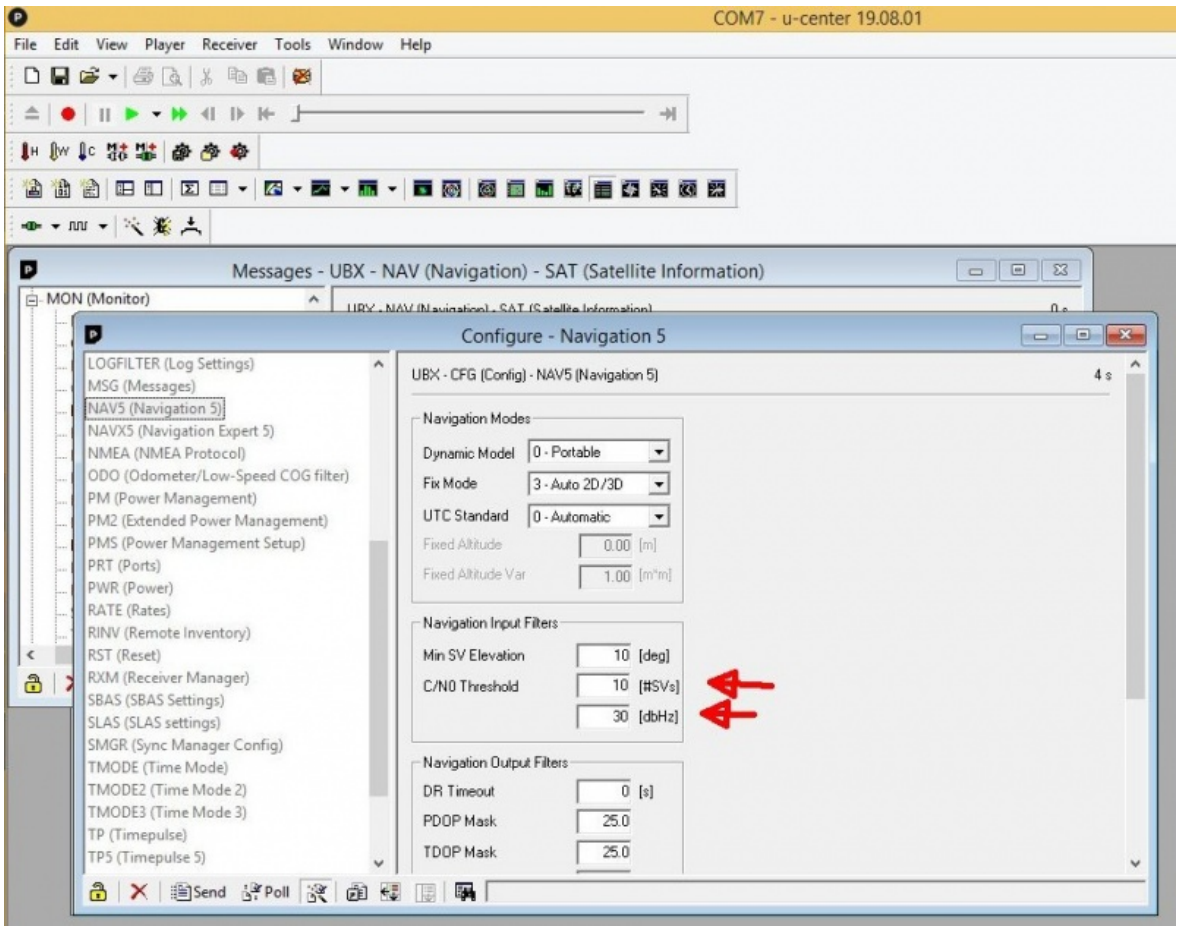
Min SV Elevation: Minimum elevation of a satellite (SV) above the horizon to start a navigation solution. Low elevation satellites may provide degraded accuracy, due to the long signal path through the atmosphere.

C/N0 Threshold: A navigation solution will only be attempted if there are at least the given number of satellites (SVs) with signals at least as strong as the given threshold.



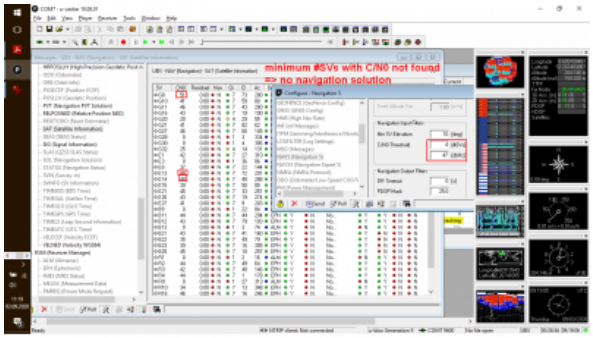


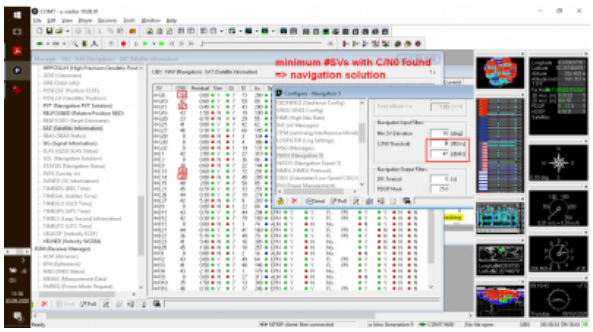




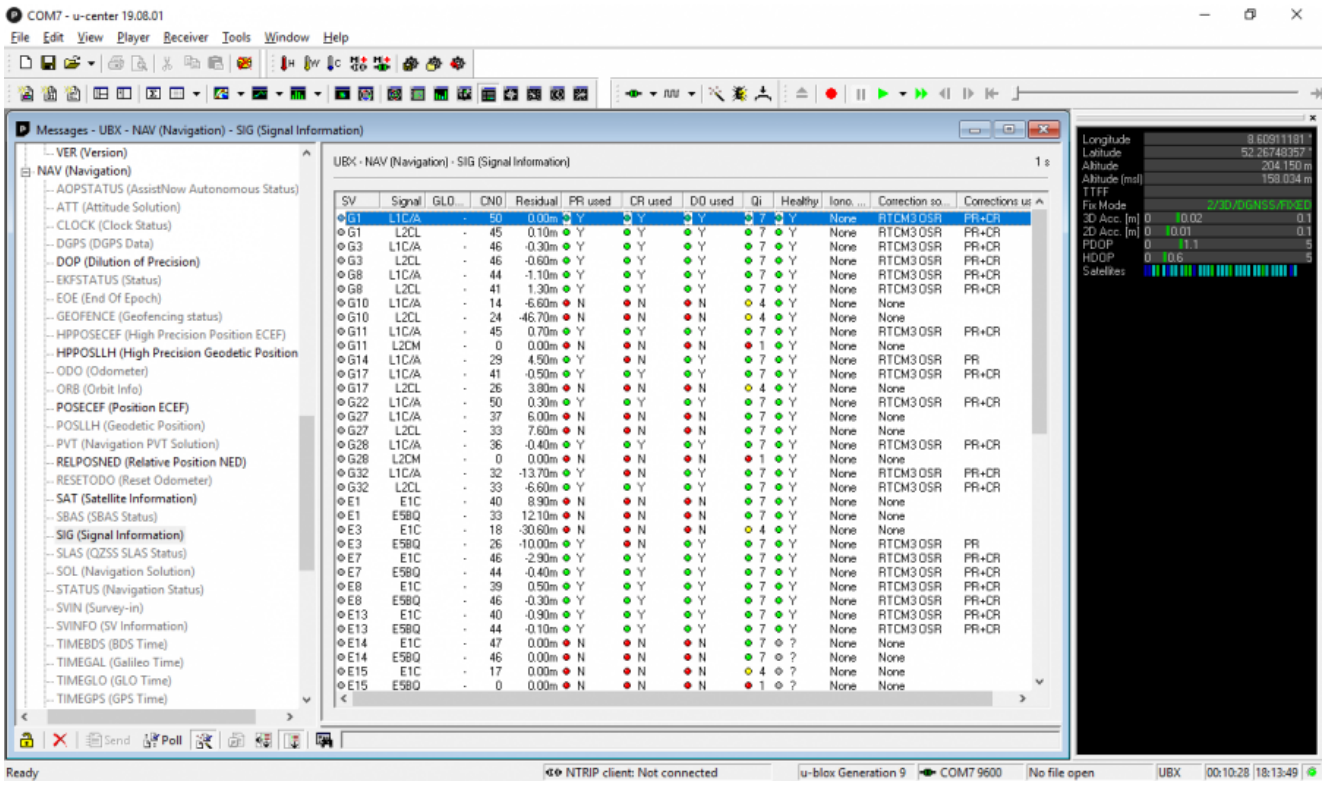
These parameters were discovered experimentally using a GPS trajectory test with limited sky view and reflections:

Tip: You can use u-center to **monitor the signal strength (CN0/dbHz) etc. of all satellites** discovered by the GPS receiver:



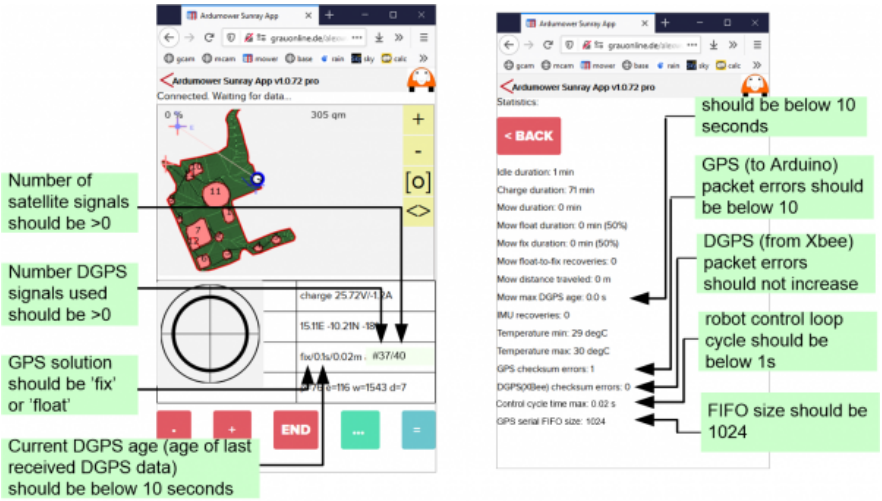


If you want to look for the **signal strength (CN0/dbHz) of the sent frequencies** (L1,L2 etc.), you can do this as well:



GPS checksum errors

If your robot position jumps sporadically and you experience ublox GPS receiver-to-Arduino transmission checksum errors ('GPS checksum errors') shown in App under Statistics->GPS checksum errors:



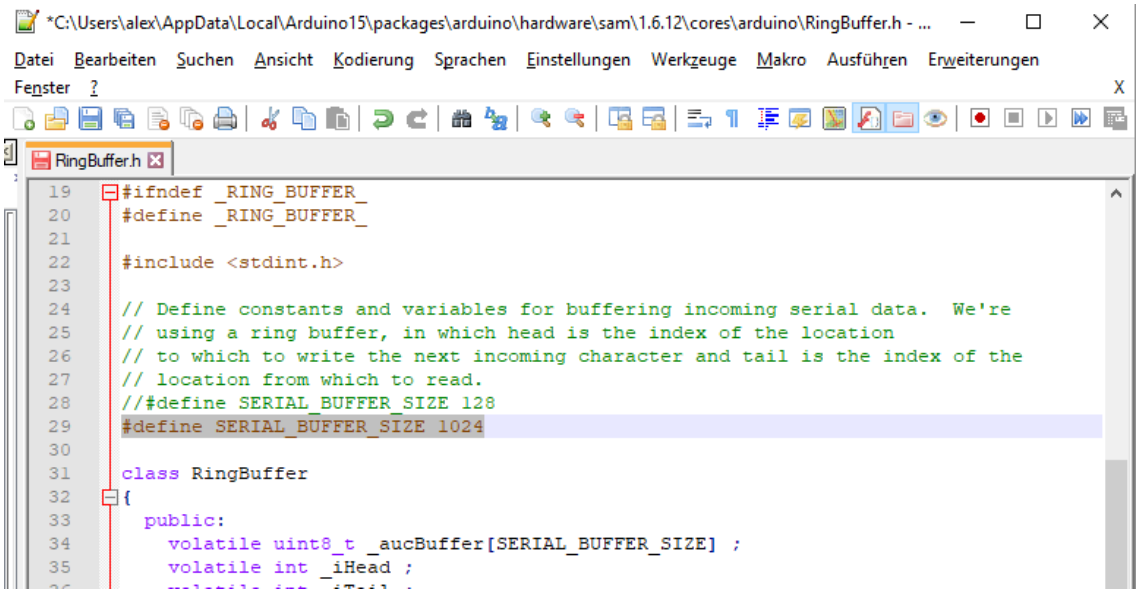
or shown in the Arduino serial monitor:

```
Arduino serial monitor:
10:40:58.012 -> ublox chka error, msgclass=1, msgid=14, msglen=24: 5!=7F
10:41:58.036 -> ublox chka error, msgclass=1, msgid=14, msglen=24: 29!=C
10:42:58.019 -> ublox chka error, msgclass=1, msgid=14, msglen=24: 2A!=DC
10:43:58.033 -> ublox chka error, msgclass=1, msgid=14, msglen=24: 5!=FF
10:44:58.001 -> ublox chka error, msgclass=1, msgid=14, msglen=24: 8A!=44
10:45:58.023 -> ublox chkb error, msgclass=1, msgid=7, msglen=5C: B5!=27
```

...then you might have to **increase the Arduino serial buffer FIFO size**:

1. In **Arduino IDE->File->Preferences** Click on 'preferences.txt' at the bottom
2. For Arduino Due: locate file **packages/arduino/hardware/sam/xxxxx/cores/arduino/RingBuffer.h**
3. For Adafruit Grand Central: locate file **packages/adafruit/hardware/samd/xxxxx/cores/arduino/RingBuffer.h**
4. Change: **#define SERIAL_BUFFER_SIZE 128** into into: **#define SERIAL_BUFFER_SIZE 1024**
5. Recompile and re-upload the Arduino sketch

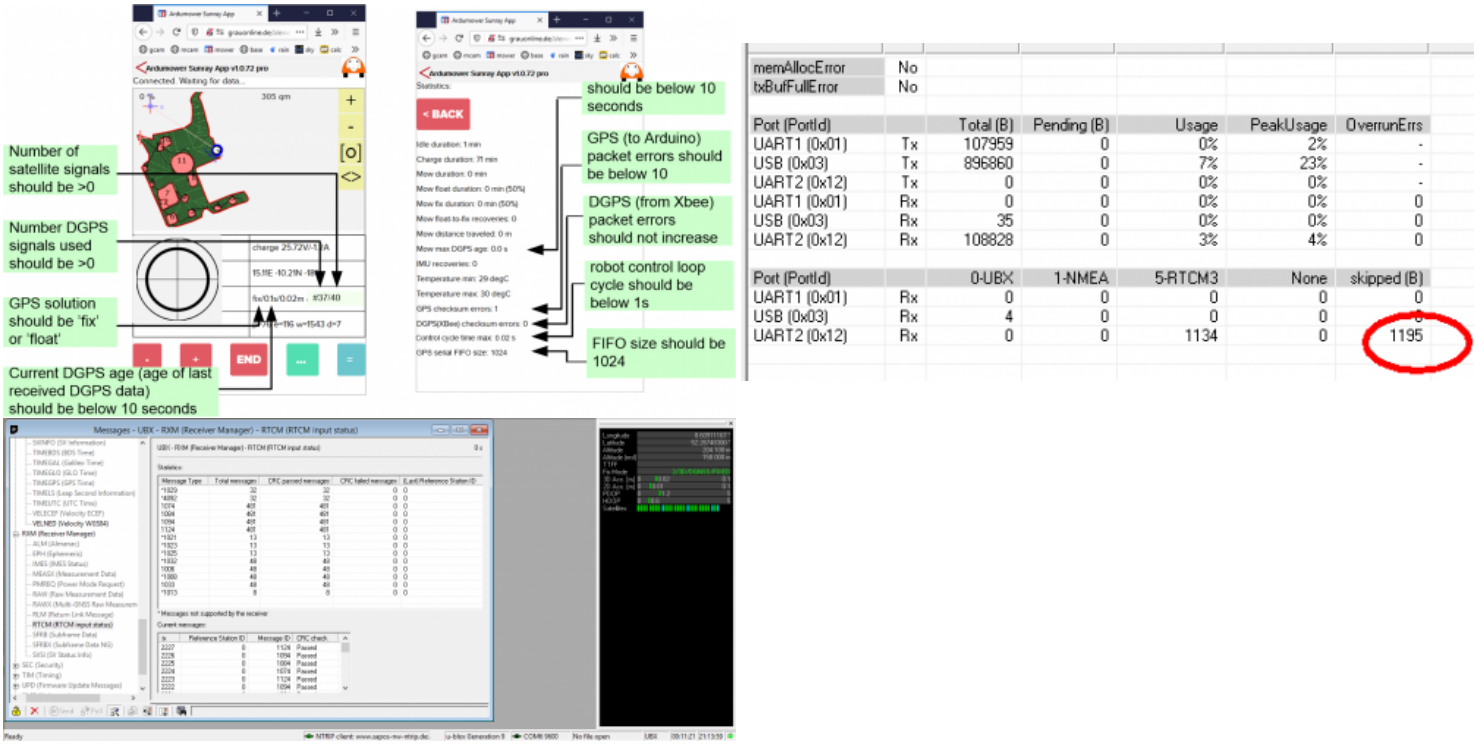
Example where the Arduino serial buffer FIFO size has been increased:



XBee RF bandwidth/corruption issues

The described GPS message rates below are now configured automatically in the Sunray firmware. Please skip this section.

We experienced that the XBee **mid-range** radio modules (2.4 Ghz) have a very limited bandwidth, activating the RTCM3 messages at highest rate (1 Hz) at the base may not work stable and data corruption can occur at the rover and the rover is not getting a stable RTK FIX. You can verify this by looking at the rover's MON-COMMS message using u-center or by looking at the App's 'DGPS(Xbee) checksum errors':

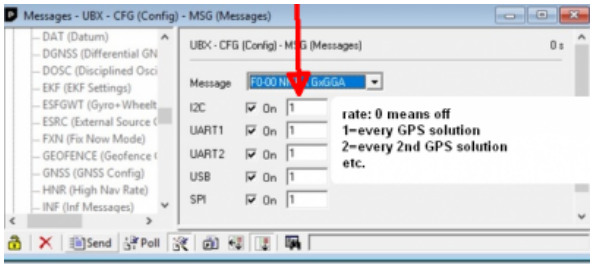


If the skipped bytes is increasing at a high rate (compared to the received bytes), your base (or rover or both) XBee is sending too much data and you can reduce the bandwidth at the base by reducing the message rates.

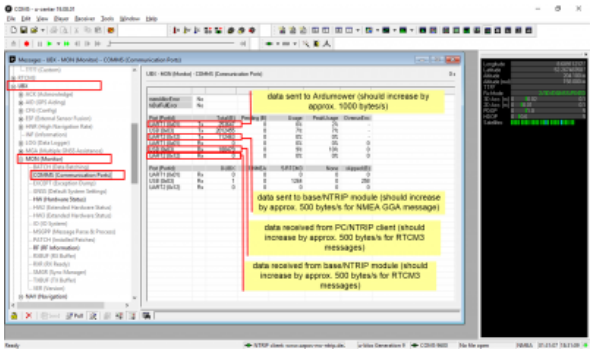
For the XBee mid-range modules the following rates have shown to reduce bandwidth and we were able to get a robust RTK FIX all the time:

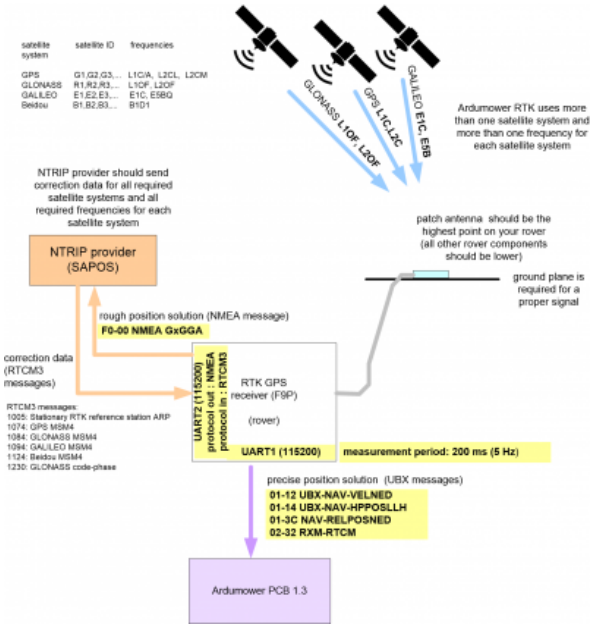
```
---- base RTCM3 message rates ---------------
rate
10     1005: Stationary RTK reference station ARP
1      1074: GPS MSM4
2      1084: GLONASS MSM4
3      1094: GALILEO MSM4
0      1124: Beidou MSM4
2      1230: GLONASS code-phase
```

You can change the message rates at the base via the configuration of the CFG-MSG message, choosing the above RTCM3 messages and setting zero (0) to turn a a RTCM3 message off or a non-zero rate value for the message rate. For example setting the rate to 1 means every GPS solution, 2 means every two GPS solutions etc. Do not forget to send and save the base configuration.



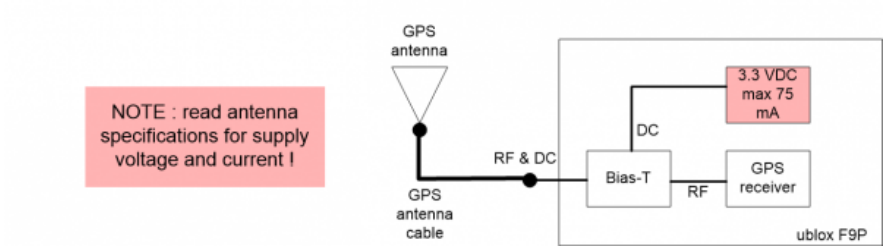
Addendum: another possible reason for limited bandwidth might be that the rover module is sending too much (unnecessary) data to the base, so stealing RF bandwidth. You can verify this using ucenter. Make sure that the rover is only sending the NMEA message GGA via UART2 (if you use NTRIP) with rate 60 or disable any outgoing messages for UART2 (if use your own base). You can change the messages sent via the configuration of the CFG-MSG message (see screenshot above).





GPS antenna selection guide

We are currently experimenting with different GPS antennas for the rover. Generally, all antennas can be used in all environments. In very difficult environments, best fix-solution results have been reported by using the Survey antenna.




```
gain of different multi-band antennas:
```

```
Survey GNSS Multiband antenna:       40 dB
Helical antenna for multiband GNSS:  33 dB
Patch antenna for multiband GNSS:    28 dB
```

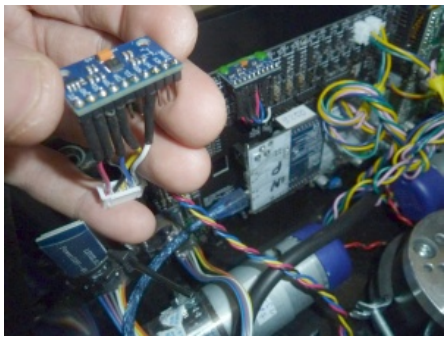
IMU, sensor fusion

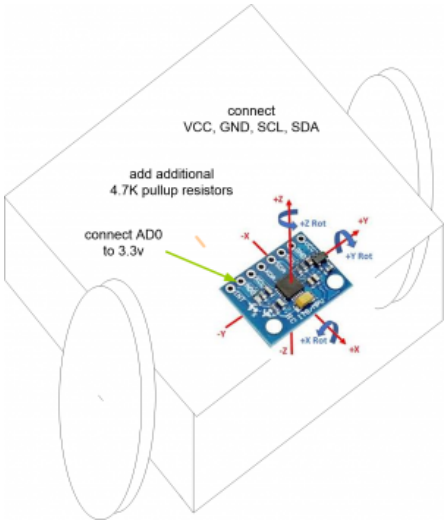
Optional: You can install an IMU (MPU6050 / MPU9150 / MPU9250 / MPU9255) (https://www.marotronics.de/9-Achsen-MPU-9250-Nine-Axis-Electronic-Compass-Accelerometer-Module-Gy-9250) like shown below to improve short-term direction measurements (in addition to wheel odometry). You can mount the IMU anywhere in the Ardumower chassis (**location/position** does not matter however **orientation** does matter! Have a look at the drawing below for correct orientation, the +X axis is pointing forward).

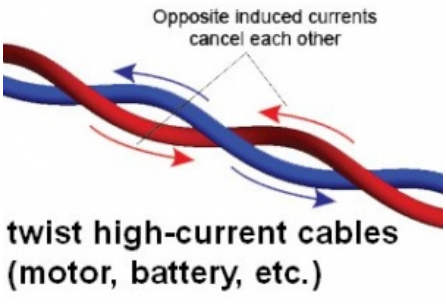
NOTE: IMU support has not been tested thoroughly (for a longer duration) yet. Make sure to configure the correct module in 'config.h'. For the shop module, choose MPU9255 in 'config.h'. If you IMU was found correctly, you should hear 8 short buzzer beeps at the mower start (automatic gyro calibration).

```
Remember: Set PCB1.3 jumper JC2 (I2C pullup level) to 3.3V for IMU connector  (if not set correctly you may experience I2C issues)
```

IMPORTANT: The I2C bus (SDA, SCL) is sensitive to EMI caused by motors etc. - **For robust I2C bus communication results, keep the I2C cables away from motors!** (see photo below) and twist all 'high-current' cables (motor, battery etc.):







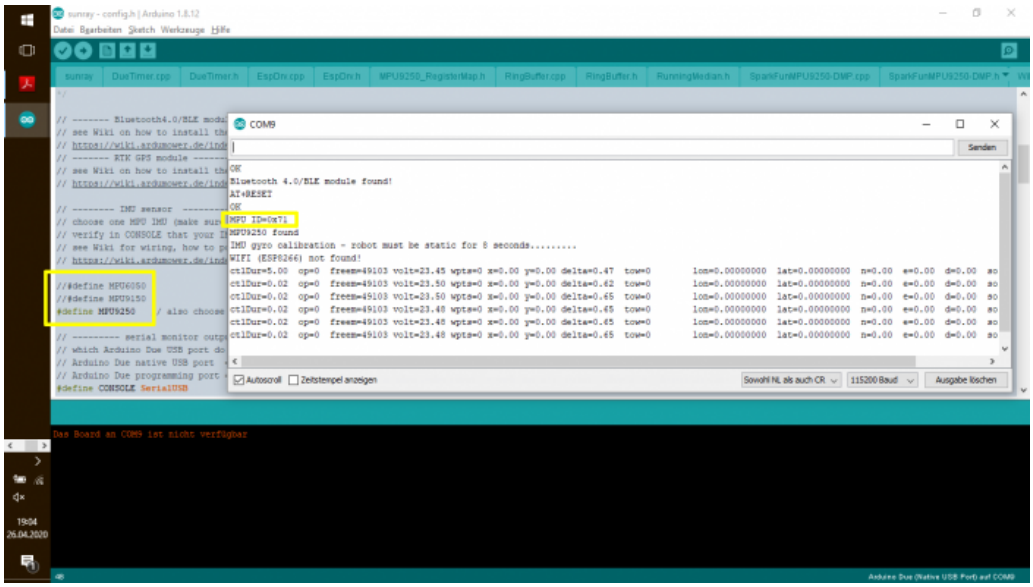
1. Connect PCB1.3_I2C2_5V to IMU VCC

2. Connect PCB1.3_I2C2_GND to IMU GND

3. Connect PCB1.3_I2C2_SDA to IMU SDA

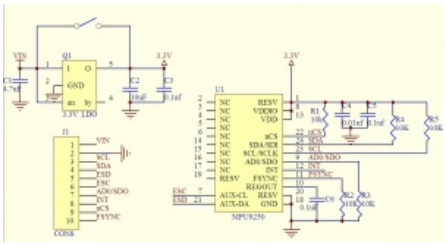
4. Connect PCB1.3_I2C2_SCL to IMU SCL

5. Connect PCB1.3_I2C2_3.3V to IMU AD0



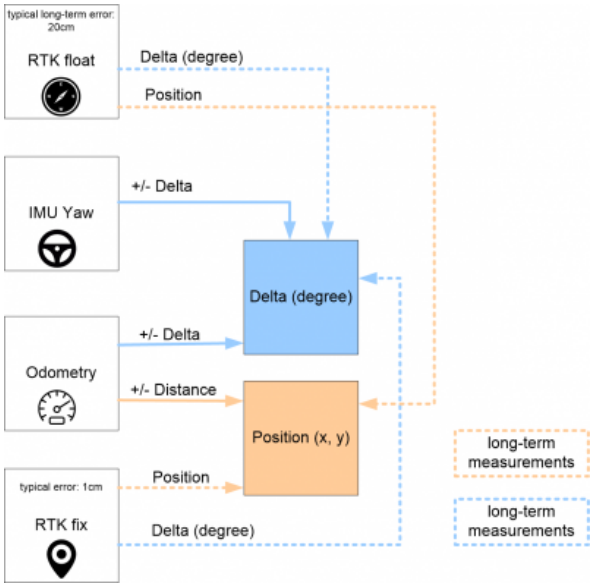
NOTE: If you experience increasing '**IMU recoveries**' (shown in the App under statistics), you can try out dividing the pullup values in half by attaching the IMU module to PCB1.3_I2C4 (instead of PCB1.3_I2C2). I2C2 has no pullups, but I2C4 does have 10k pullups. Together with the 10k pullups on the IMU

module this will divide the overall pullup values in half to 5K.



The following image shows how the sensor fusion of all data (RTK GPS, odometry, IMU) happens:

Click here to see a video on how to verify your IMU sensor is working correctly (https://www.youtube.com/watch?v=OEUQSRzVzwE)



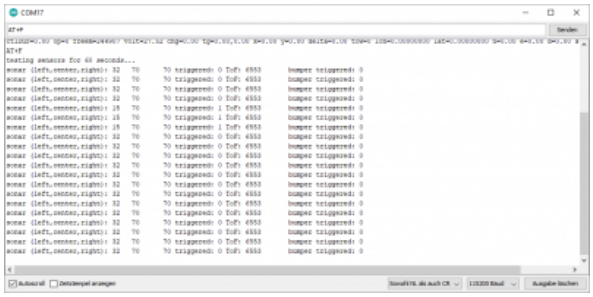
Ultrasonic sensor

Optional: You can install up to three ultrasonic sensors (https://www.marotronics.de/HC-SR04-Ultraschallsensor-Ultrasonic-Ranging-Module) like below to add **obstacle detection** (in addition to the GPS feedback-based **obstacle detection**).

PCB1.3 wiring (SonarL, SonarC, SonarR):

```
Ultrasonic Module VCC (+5V)  – PCB VCC (+5V)
Ultrasonic Module GND        – PCB GND
Ultrasonic Module Trigger    – PCB Trigger
Ultrasonic Module Echo       – PCB Echo
```

Note: You can **test the ultrasonic sensors** using the **sensor test**. Start Arduino serial monitor and send 'AT+F' (with ENTER) to the Arduino to start the sensor test.



Extending WiFi range with outdoor access point

These WiFi access points have been tested and are recommended for **outdoor use** (and typically have an extended range):

- TP-Link EAP110 (or EAP 225) Outdoor 2.4 Ghz 300 MBit outoor access point
- Ubiquiti UniFi UAP-AC-M Wireless Access Point
- ...

Portable WiFi router for NTRIP

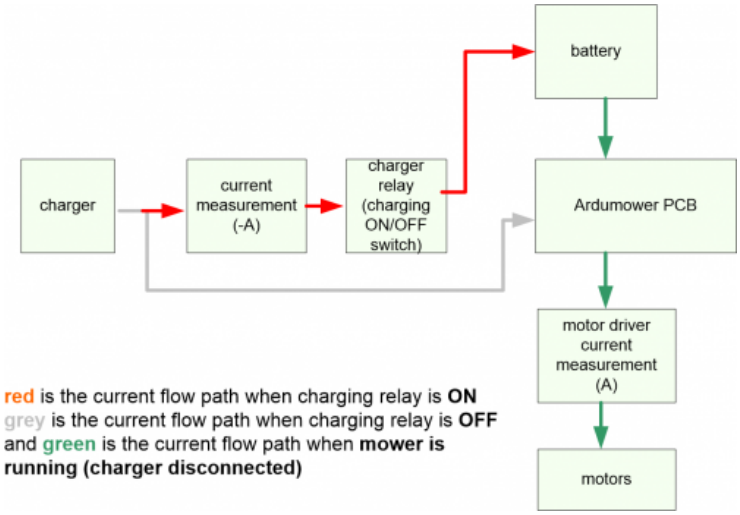
For your first NTRIP tests (or even as permanent installation), you might use a portable 4G/WiFi router. Such 4G modem could be used where the WiFi coverage is limited. In addition, you can operate multiple WiFi devices (Ardumower PCB WiFi module, NTRIP client WiFi module, ESP32-CAM WiFi module etc.) via this portable 4G WiFi router. NOTE: You may have to use **virtual private network (VPN) protocol** to be able to access all devices from the Internet. Using VPN, the 4G router will connect to some VPN server (e.g. your private Fritzbox) and also provide an WiFi access point (AP) to all Ardumower WiFi modules. Both the robot and the App can then use the connected VPN server to connect to. Without a VPN server, an additional server would be required to access the robot from within the Internet and the VPN server satisfies this requirement.

Here are some example devices:

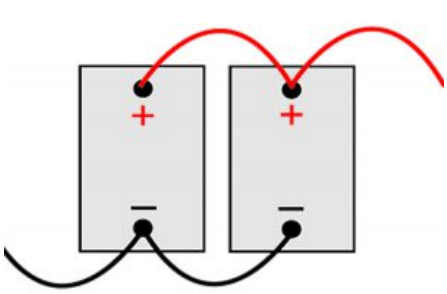
- HUAWEI E8372 WiFi/WLAN LTE Modem (only needs USB power)
- ...

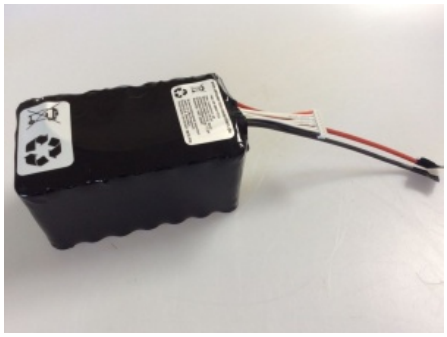
Longer battery operation time

What electrical current does the App measure and show when in charging (App shows '-A') and mowing mode (App shows 'A'):



Tip: for longer battery operation time, connect two Ardumower batteries in parallel:

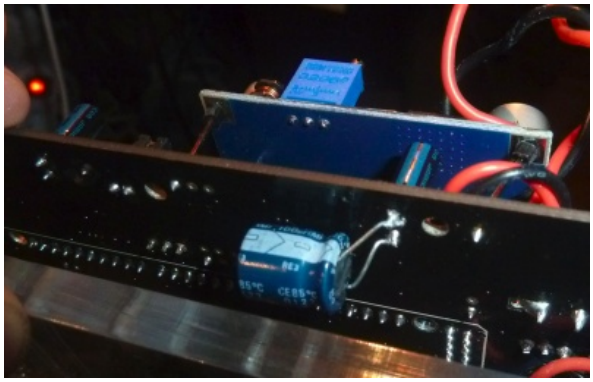




Or much easier: There are now **two variants** of the Ardumower battery pack, **125 Wh(5Ah)** and **250 Wh(10Ah)**: https://www.asn-shop.de/Ardumower-Rasen-Roboter-Akku

Automatic battery switch off

You can set jumper **JP8 to 'Automatic'** (near DC/DC module) to **enable automatic battery switch-off** for a) **undervoltage** and b) if the robot is in **idle** mode (you can choose both situations in config.h). If you enable automatic battery switch-off, it is recommended to **add an additional capacitor (100 uF or higher, 63V)** below the existing capacitor as shown below to be able to flash the Arduino **without a sudden PCB switch-off**.



Docking

Using **two docking pins connected with your charger, your robot can go charging automatically.**

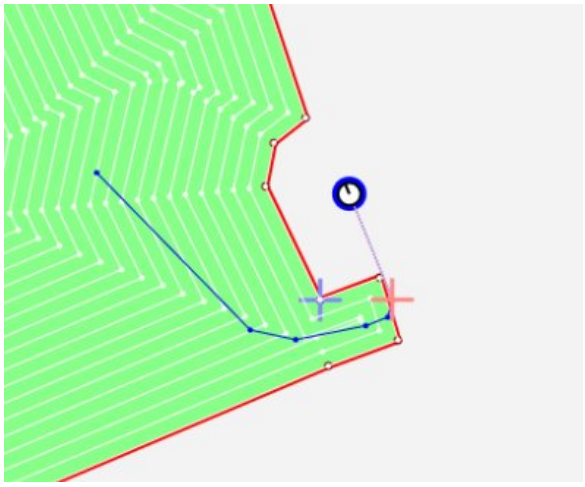
Ideas for building a docking station: https://forum.ardumower.de/threads/ladestation-aus-aluprofilen.23905/

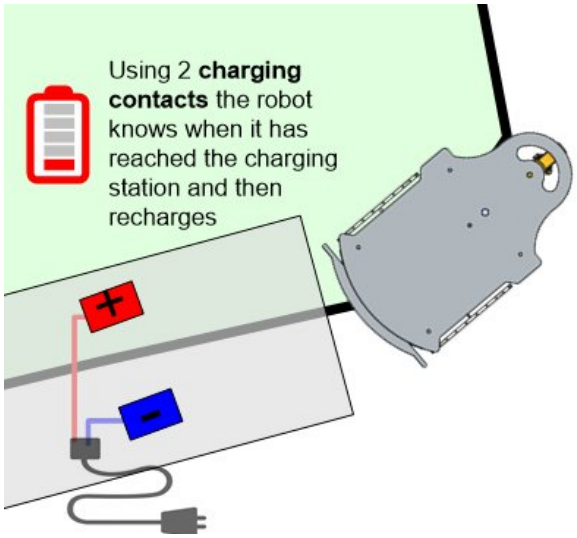
Further building ideas: https://wiki.ardumower.de/index.php?title=Charging_station

Docking/undocking demo video 1: https://www.youtube.com/watch?v=GRlvjBs7_tg

Docking demo video 2: https://www.youtube.com/watch?v=PSbmBYGLZBA

Docking prototype video: https://www.youtube.com/watch?v=03seYUKiJcc





Steps to use docking/undocking in the App:

1. **Record docking points**: Activate **Record mode: dock** in the App, then manually steer your robot mower from a position with good sky view (good GPS signal) (first docking point) into the docking station until the docking contacts (last docking point), and add docking points via the App during this process.

NOTE: The **last docking point** (for the docking contacts, shown bigger) **should be moved slightly (30cm) behind the actually docking contacts** via the App point editor mode (symbol [.]), so the robot tries to reach it (and it doesn't matter if it cannot actually reach that point).

2. To **undock**, the mower **must have touch to the docking contacts** (the App shows 'charge'). Then press 'Start' in the App to undock. The mower will drive in reverse out of the docking station to the first docking point and continue at the last mowing point (or start at the first mowing point) . If there is **no touch to the docking contacts**, the mower will think it is out of the docking station and drive directly to the mowing point without actually undocking. Note that no GPS float solution is used during undocking. Only IMU and odometry and (if available) a GPS fix solution is used during undocking.

3. To **dock**, press 'Dock' in the App. The mower will calculate a path to the first docking point, and then follow the docking points until the docking contact.

How much energy does the robot consume in the docking station? For your information, here are **power consumption measurements when the robot is not charging the battery**:

Ardumower PCB1.3 with Bluetooth + WiFi + RTK-GPS: 7 Watt (RTK-GPS: 1.5 Watt, WiFi: 1 Watt, Arduino Due: 2 Watt)

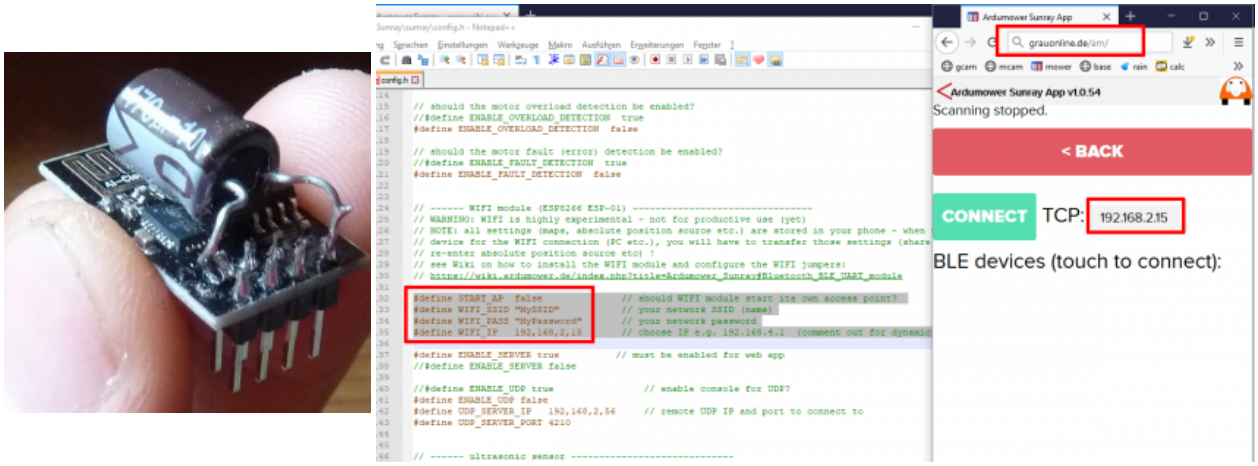
WiFi module

Optionally, you can add a ESP8266-01 WiFi module (using ESP8266 NONOS SDK V2.2.1 firmware) found in the shop (https://www.marotronics.de/ESP8266-WIFI-Wlan-Serial-Modul-ESP01-fuer-Arduino) to your PCB1.3 and use it with the Sunray firmware.

Demo video: https://www.youtube.com/watch?v=onsTfae-8VQ

NOTE: all settings (maps, absolute position source etc.) are stored in your phone - when using another device for the WIFI connection (PC etc.), you will have to transfer those settings (share maps via app, re-enter absolute position source etc)!

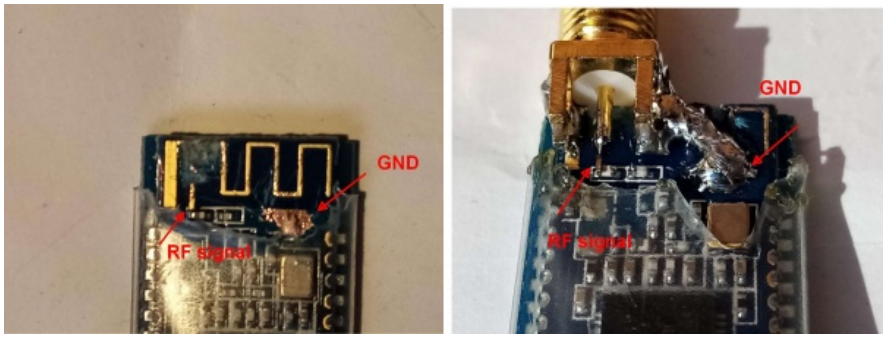
NOTE: Never connect with two devices (e.g. PC and phone) at the same time! (Close the App on the phone before using WiFi on the PC)



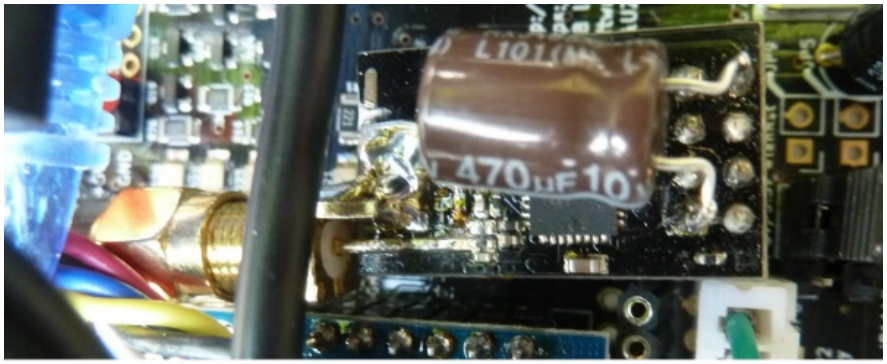
1. Ensure your ESP module is using firmware 2.2.1 (https://www.espressif.com/en/support/download/sdks-demos) like the Marotronics module
2. Make sure you have set the **WiFi jumpers** (shown here (https://wiki.ardumower.de/index.php?title=Ardumower_Sunray#Bluetooth_BLE_UART_module)).
3. If you experience connection issues, you may have to **add an additional capacitor** (e.g. 470 uF/10V) to the module as shown in the photo. Also, do **not use additional cables** in between PCB1.3 and WiFi module if you experience connection issues.
4. Look into firmware file **config.h** on how to configure SSID and (a static) IP.
5. Look into the **serial console (Download section, step 7) (https://wiki.ardumower.de/index.php?title=Ardumower_Sunray#Download.2C_Arduino_Code.2C_Firmware)** if you experience connection issues and to debug the connection process.

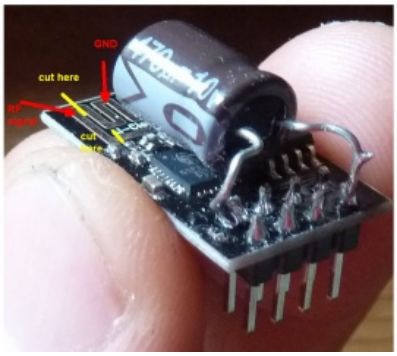
Bluetooth Low Energy (BLE) and WiFi external antenna hacks

This might be the right hack for you :-) This is how I added an external SMA antenna to the Bluetooth 4.0/BLE UART module (CC2540) (https://www.marotronics.de/HM-10-Bluetooth-BLE-BT-40-CC2541-CC2540-fuer-Arduino-iOS-Android-Low-Energy) to increase range to approx. 20m. Happy hacking :-)



And this is how I added an external SMA antenna to the ESP8266-01 WiFi module (https://www.marotronics.de/ESP8266-WIFI-Wlan-Serial-Modul-ESP01-fuer-Arduino)





⚠ WARNING! Modifications to RF antennas, RF signal pathes on PCB's etc. are risky and you will loose general permission to operate the device - you may radiate additional unknown signals due to your modifications. Be warned of that!

What are the differences between the Ardumower and ArduSimple ublox receiver configurations

ArduSimple base/rover PCB port connections:

```
UART1: connected to Ardumower PCB1.3 (rover only)
UART2: connected to XBee module
USB:   connected to computer (u-center)
```

Ardumower base (ublox F9P) configuration (identical with ArduSimple base config):

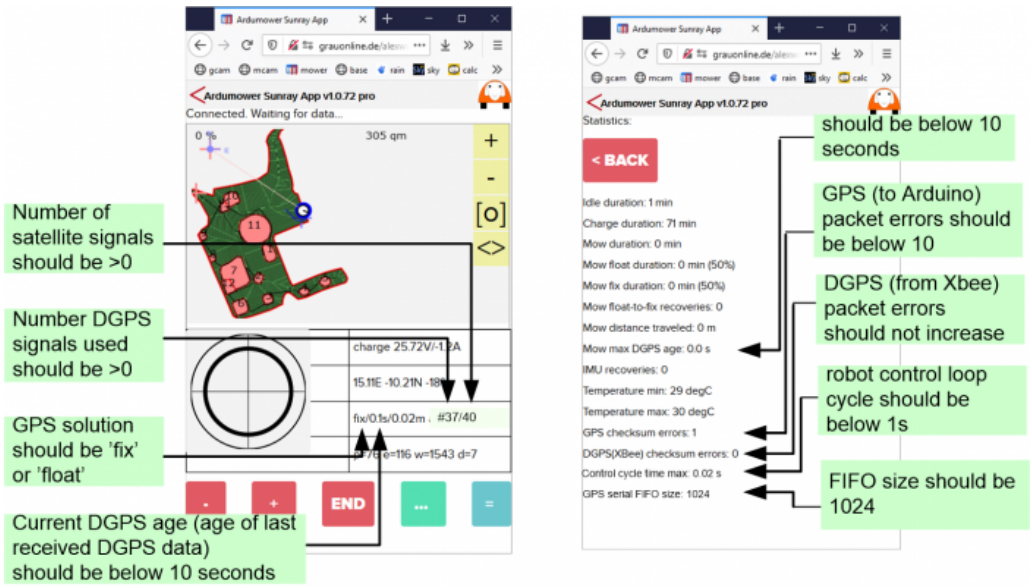
```
PRT (ports) protocol UART2 (XBee) in:     RTCM3
            protocol UART2 (XBee) out:    RTCM3
            baudrate UART2 (XBee):        115200 baud
RATE (rates) measurement period:          1000ms (1 Hz)
TMOD3 (Time mode3) mode:                  Fixed mode
  Fixed Position:                         Your base lat/lon coordinates
MSG (messages) for UART2 (XBee)           transmit frequency (10 means message is sent every 10 solutions):
  F5-05 RTCM3.3 1005 Stationary ARP       1
  F5-4A RTCM3.3 1074 GPS MSM4             1
  F5-54 RTCM3.3 1084 GLONASS MSM4         1
  F5-5E RTCM3.3 1094 GALILEO MSM4         1
  F5-7C RTCM3.3 1124 Beidou MSM4          1
  F5-E6 RTCM3.3 1230 GLONASS code-phase   1
```

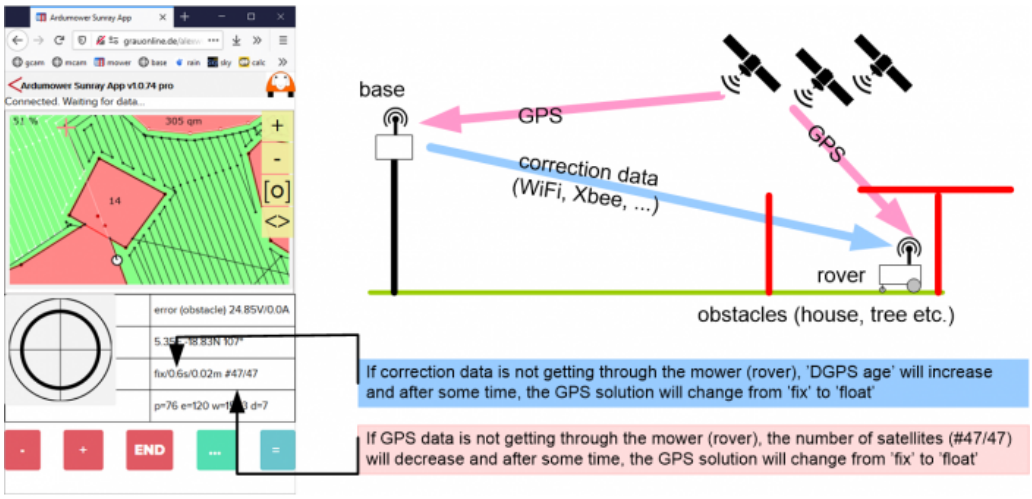
Ardumower rover (ublox F9P) configuration:

```
additional activated messages (or changed message frequency) for UART1+USB:
MSG (messages) for UART1(Ardumower)+USB   transmit frequency (60 means message is sent every 60 solutions)
  F0-00 NMEA-GxGGA                        60
  01-07 UBX-NAV-PVT                       10
  01-12 UBX-NAV-VELNED                    1
  01-14 UBX-NAV-HPPOSLLH                  1
  01-3C UBX-NAV-RELPOSNED                 1
  01-43 UBX-NAV-SIG                       10
  02-32 RXM-RTCM                          5
additional activated messages for UART2(XBee)+USB:
  MSG (messages) F0-00 F0-00 NMEA GxGGA   60
RATE (rates) measurement period:          200ms (5 Hz)
PRT (ports) baudrate UART1 (Ardumower):   115200
            baudrate UART2 (XBee):        115200
            protocol out UART2 (XBee):    NMEA
            protocol in UART2 (XBee):     RTCM3
NAV5 (navigation 5) input filter:
  Min SV elevation                        10          default:  10
```

C/N0 Threshold #SVs	10	0
dbHz	30	0

Troubleshooting





- You **cannot see the Blutooth BLE module** listed in the App via 'Connect'? If not, ensure that you give the App Bluetooth permissions.
- Can you drive the mower via the App '**manual control**' without any issues? If not, verify the motor odometry settings via a motor test (see odometry section above).
- Does the mower have **issues to rotate** ('delta' shown in the App) correctly and is it missing an IMU? If yes, add an IMU (e.g. 9250, see IMU section above).
- Do you get constant '**IMU tilt**' errors and cannot get rid of them? Your IMU may be broken. Check forum on how to verify your IMU (see below).
- Do you sporadically get '**IMU timeout**' errors? See IMU section above on how to shorten IMU cables.
- Does the '**GPS checksum error**' shown in the App (Statistics) increase or does the **robot position jump sporadically**? If yes, check section above (GPS checksum error) on how to increase Arduino serial FIFO size.
- Does the RTK **position (N,E shown in the App) jump** after a mower restart and are you using NTRIP/SAPOS? If yes, verify you are using absolute position mode in the App (see position source mode section above).
- Does the '**DGPS age**' shown in the App increase too much (>5 seconds)? If yes, verify your WiFi or XBee connection (see section extending outdoor WiFi above on how to improve WiFi connection). Also, verify the LEDs on the GPS modules - at the base, the LED 'GPS->XBEE' should blink and on

the rover, the LED 'XBEE->GPS' should blink. Also, verify that your base is configured for 'Fixed Mode' and is getting a '3D' position solution (see section 'RTK base / Your own RTK base' above).
- Does the '**DGPS checksum error**' shown in the App (Statistics) increase? If yes, verify your WiFi or XBee connection (see section XBee corruption issues above).
- Is the '**number of DGPS signals used**' show in the App (example: #37/40 means 37 signals where DGPS was used versus 40 total signals) almost zero? If so, your base is not sending sufficient correction signals or the rover could not use the DGPS signals.
- Do you sporadically get '**GPS invalid**' solutions? If yes, verify your WiFi or XBee connection (see above sections extending outdoor WiFi and XBee corruption issues). Also, verify your PCB1.3 DC/DC module voltage output.
- Do you get **GPS invalid** (after some time) that never returns back to a float or fix solution at locations where it normally does quickly? Or is the **LED 'XBEE>GPS' flickering and not blinking**? If so, your GPS module might be broken and it's advisable to try another one.
- Do you have issues to get a '**fix**' during manual steering and recording your map? If yes, wait for a fix, take your time and always drive the mower slowly.
- Do you have issues to get a '**fix**' during automatic mowing? If yes, try out Hartmut's ublox config (found in Sunray GitHub).
- Do you still have issues to get a '**fix**'? Use a ground plate (10x10cm) and connect it to PCB ground.
- Does the '**control cycle time max**' shown in the App (Statistics) increase too much (>0.02s)? If yes, your WiFi access (or something else) may slow down the robot control loop too much and **robot tracking errors may appear** (example: a max. conrol cycle of 1s would mean the robot motors were running without active control for max. 1s).

-

IMU sensor tilt issues: https://forum.ardumower.de/threads/imu-tilt-error-9250.23864/

GPS/RTK WiFi NTRIP and RTK non-stable fix issues:

- https://forum.ardumower.de/threads/frage-zum-gps-rtk-wifi-ntrip.23866/post-41712
- https://forum.ardumower.de/threads/welche-gps-antennen-nutzt-ihr-wie-sieht-eure-grundplatte-aus-alles-rund-um-den-gps-empfang.23709/post-41762

No FIX after ublox FW upgrade:

- https://forum.ardumower.de/threads/kein-fix-oder-float-mehr-nach-fw-update.23935/

ublox f9p firmware upgrade guide:

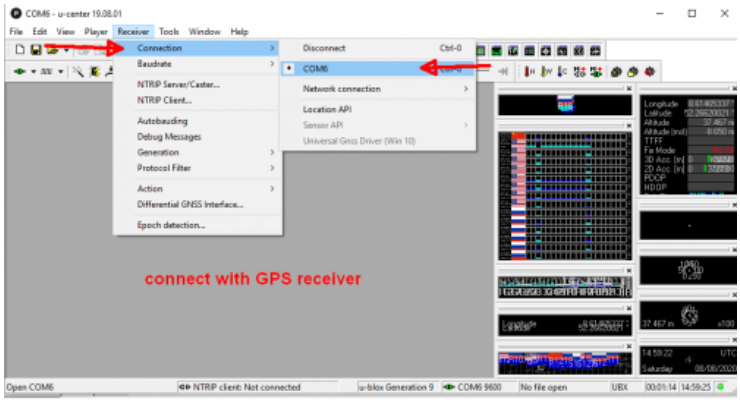
- https://www.ardusimple.com/zed-f9p-firmware-update-with-simplertk2b/

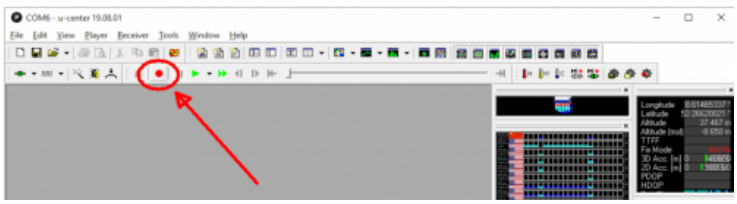
How to record GPS data

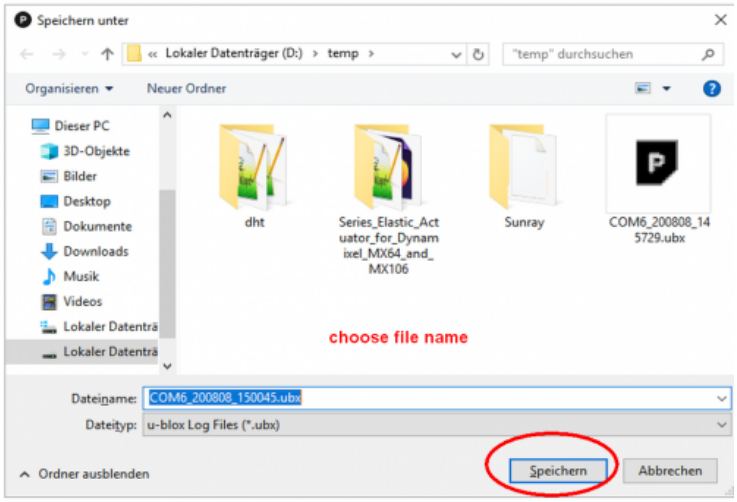
For debugging purpose, all data sent by the ublox receiver (and received by the Ardumower PCB) can be recorded into a file via u-center. This log file can then be used to play back again the recorded data. So, it simulates the GPS receiver used during the recording.

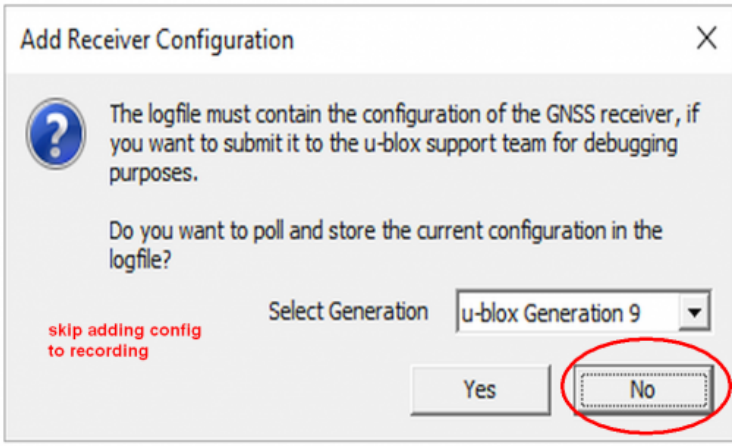
Steps to record your GPS receiver data:

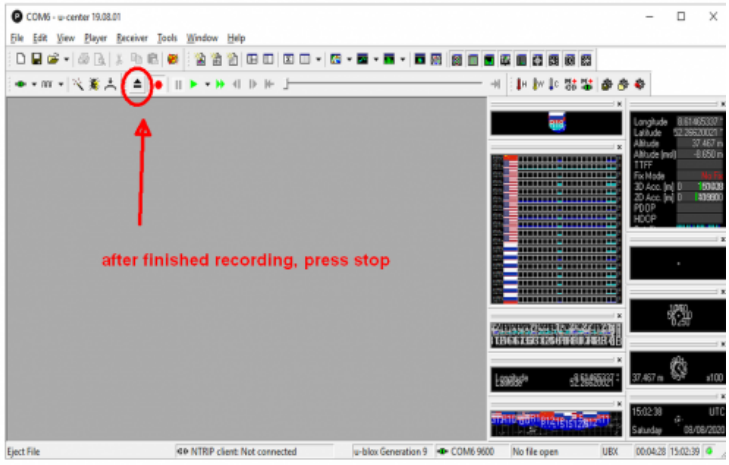
1. Connect your laptop computer (Windows) to the simpleRTK2B rover module **USB port** marked as '**POWER+GPS**'.
2. Download ublox u-Center, install it and start it: **https://www.u-blox.com/en/product/u-center**
3. Choose '**Receiver->Connection**' and choose your **rover module COM port**.
4. Click on red '**record button**' and choose a file name for the recording.
5. If being asked to save the receiver configuration, choose 'No' to skip that.
6. Now everything is not only sent from the GPS receiver to the Ardumower PCB but also saved in the record file. After finished the session, press **stop button** to stop recording.











Datasheets

XBee Long Range module, up to 14km, 13 dBm ERP/20mW (Xbee SX 868 xb8x-dmrs-001)
(https://www.mouser.de/datasheet/2/111/Digi%20International_06292017_XB8X-DMRS-001-1163648.pdf)

u-blox GNSS Antennas Application note (UBX-15030289) (https://www.u-blox.com/sites/default/files/products/documents/GNSS-Antennas_AppNote_%28UBX-15030289%29.pdf)

ublox Multi-band, high precision GNSS antennas (ANN-MB series) (https://www.u-blox.com/sites/default/files/ANN-MB_DataSheet_%28UBX-18049862%29.pdf)

u-blox F9 high precision GNSS receiver interface description (https://www.u-blox.com/en/docs/UBX-18010854)

Data privacy

When sharing your maps in the App, all data is saved anonymously and without any GPS coordinates. All position data is saved only as distance (North, East) in meters between the recorded points and your base. All data is kept confidential and according to German protection of data privacy. It is not possible to identify any locations or any persons with this anonym data.

Discussion / questions / forum thread

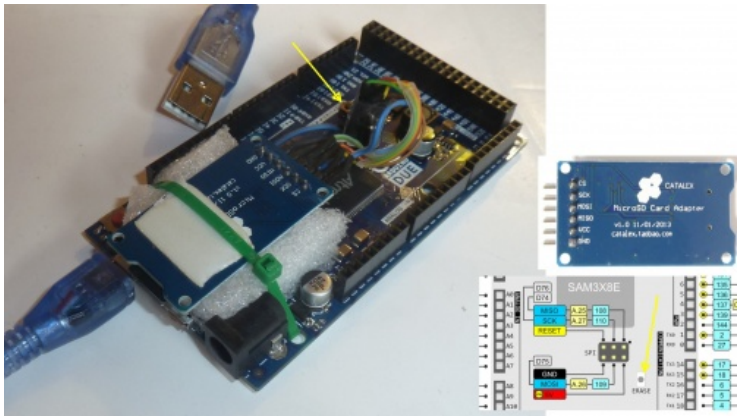
If you have any doubt, or if you are unsure, please ask in the Ardumower forum for help (https://forum.ardumower.de/threads/sunray-firmware-goes-rtk.23690/#post-40042):

Link to forum: https://forum.ardumower.de/threads/sunray-firmware-goes-rtk.23690/

SD card module

Optionally, you can add an SD card module (found in the shop (https://www.marotronics.de/Micro-SD-Kartenmodul-SPI-Card-Reader-Kartenadapter-fuer-Arduino)) to your Arduino Due and use it with the Sunray firmware to save uploaded maps or log serial output data.

NOTE: The Adafruit Grand Central M4 already has an SD card reader built-in.



The SD card reader can be connected directly to the Arduino Due SPI pins.

Wiring:

```
CATALEX MicroSD card Adapter     Arduino Due SPI pins
CS    ------------------------   Arduino Due pin 46  (chip-select pin, not an SPI pin)
SCK   ------------------------   SCK
MOSI  ------------------------   MOSI
MISO  ------------------------   MISO
VCC   ------------------------   5V
GND   ------------------------   GND
```

SD card logging

For the very rare case that the Arduino hangs/stucks at a certain library, the **watchdog** in the Arduino has been programmed by the Sunray firmware to **reset** the Arduino.

However, if this reset happens too often, and you have the feeling it is a software issue, **SD card logging** might help to find out the code location for the hang/stuck.

IMPORTANT: For a full inspection, we will need both, your log files AND your compiled binary (sunray.ino.elf) !

1. **Insert a FAT32 formatted microSD card** into the Adafruit Grand Central M4

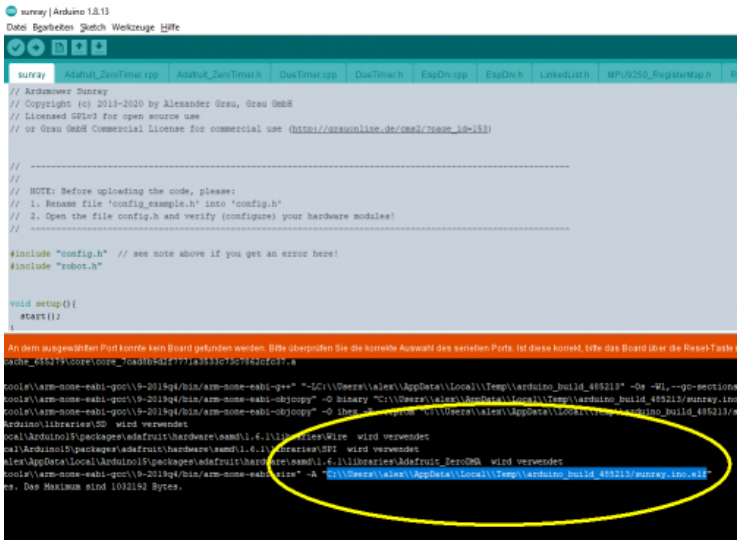
2. **Activate SD card logging** in your config.h

3. **Locate the compiled 'sunray.ino.elf' file and make a copy of it** (because Arduino IDE will delete the binary when closed):

3.1. In Arduino IDE, enable 'full output during compilation and upload' via menu File->Preferences

3.2 **Compile** the sunray.ino file

3.3 Look into the Arduino IDE output **to find out the location** of the compiled 'sunray.ino.elf' file



3.4 Using Windows Explorer, go into the shown folder and **make a copy/backup of the 'sunray.ino.elf' file**.

4. **Run your robot**. If some unexpected RESET appears, the Arduino will automatically save additional 'stack dump' information in the log file that corresponds to your compiled binary (sunray.ino.elf). Therefore the stack dump information only makes sense for your compiled binary.

For further inspection, **send us** both your **SD card log files AND corresponding binary (sunray.ino.elf)**.

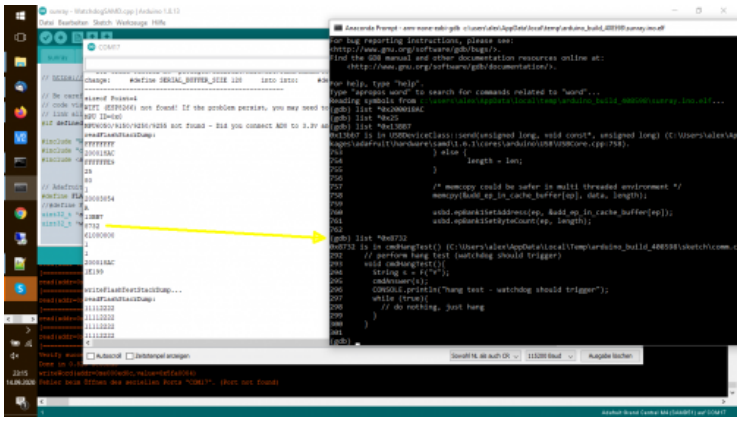
Developers/users can inspect the stack dump (found in the log files at the top) as follows. The stack dump contains RAM addresses that the CPU uses when calling a sub-function to remember the code address where to get back after completing that sub-function. By inspecting the stack addresses one can list all code locations (until the point where the CPU is running).

1. Locate the ARM GDB debugger in your Arduino Adafruit package and run it on the binary file (sunray.ino.elf):

```
> C:\Users\alex\AppData\Local\Arduino15\packages\adafruit\tools\arm-none-eabi-gcc\9-2019q4\bin>arm-none-eabi-gdb
    c:\users\alex\AppData\local\temp\arduino_build_408598\sunray.ino.elf
```

2. To list the code for an arbitrary address found in the stack dump, use the GDB list command - Example: the stack dump contains address '0x8732' and you want to find out if that is a valid code address and what code is at that address:

```
(gdb) list *0x8732
```



R/C model

In addition to the App, you can steer the robot via an R/C model controller. The R/C pinout (P13) is:

```
P13_1  +5V              ----- R/C model controller VCC
P13_2  GND              ----- R/C model controller GND
P13_3  pinRemoteMow     ----- R/C model controller speed and direction channel (forward/backwards)
P13_4  pinRemoteSteer   ----- R/C model controller steering channel (left/right)
P13_5  pinRemoteSpeed   not used
P13_6  pinRemoteSwitch  not used
```

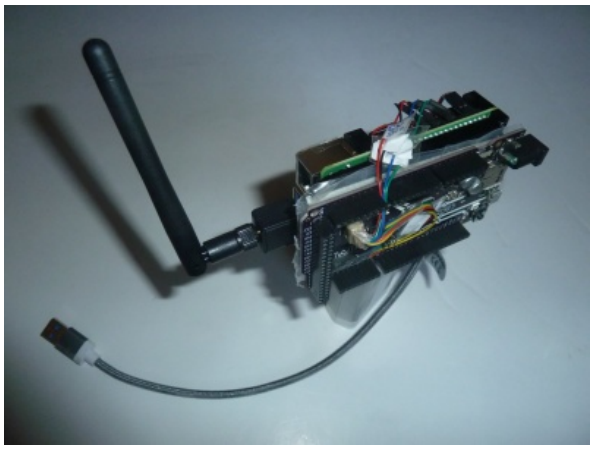
To activate R/C mode, power on robot and press START button (P20) for 3 seconds. Press again START button (P20) for 3 seconds to turn off R/C mode.

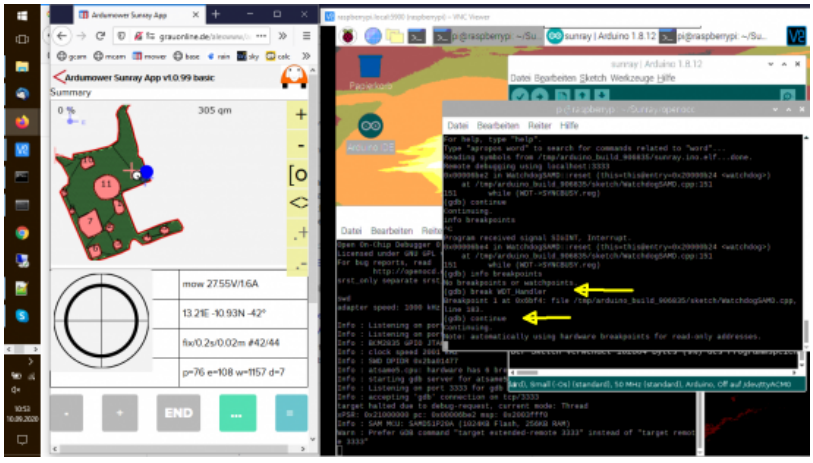
Hardware debugging

For the very rare case that the Arduino hangs/stucks at a certain library, the **watchdog** in the Arduino has been programmed by the Sunray firmware to **reset** the Arduino.

However, if this reset happens too often, and you have the feeling it is a software issue, **hardware-debugging** might help to find out the code location for the hang/stuck.

In the Github folder 'openocd' (https://github.com/Ardumower/Sunray/tree/master/openocd) you will find a 'readme.txt' that describes how to connect a Raspberry PI to the Arduino for hardware-debugging. The idea is to set a 'breakpoint' at the **watchdog interrupt** for the case that the Arduino resets. The hardware-debugger (Raspberry PI in this case) can then be used to get a **backtrace** of the last function calls to locate the problem in the code.





Retrieved from "https://wiki.ardumower.de/index.php?title=Ardumower_Sunray&oldid=8213"

- This page was last modified on 17 October 2020, at 10:24.