Marvelmind Indoor Navigation System
Operating manual

v2018_09_04

www.marvelmind.com

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1. Version changes

V2018_08_30

- New SW features descriptions
- New Dashboard view descriptions

V2018_08_03

- Calibration of accelerometer added
- F.A.Q. updated
- Troubleshooting guide added
- Refreshed links
- Player feature description
- IMU feature description
- Minor fixes

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- SW features paragraph updates
- General updates
- Sending path to robot
- Radio frequency band switch in latest Dashboard version
- Sending path to robot
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- FAQ updates

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- Added Sensors settings
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- Fresh Dashboard screenshots
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- Added estimation of accuracy of distances measurement
- Added Raw inertial sensors data
- Added Communication of Pixhawk with Marvelmind mobile beacon
- Added Optimal settings for stationary beacons in small and big rooms
- Added Optimal settings for noisy environment

V2017_07_20

- Cleaned up description and some corrections were added
- Description of HW v4.5 removed from this manual and given in the previous version of the manual, which can be found here: http://www.marvelmind.com/pics/marvelmind_navigation_system_manual_HW_v4.5.pdf
- Description of HW v4.9 added
- Introduced plastic housing for beacons and modem
- Introduced 915MHz variant for the US market (HW v4.9 only)
- General updates and description improvements
- Submaps added
- Description of Dashboard buttons
- HEX and DFU firmware general updates + new links
- Obtaining raw data from inertial sensors

- Settings to get correction north direction

2. Executive summary

Marvelmind Indoor Navigation System is an off-the-shelf indoor navigation system, designed to provide precise (±2cm) location data to autonomous robots, vehicles (AGV), and copters. It can also be used to track moving objects via mobile beacons attached to them. Other applications include, for example, forklifts, virtual reality (VR) systems, helmets for construction workers or miners, etc.

The navigation system consists of a network of stationary ultrasonic beacons interconnected via radio interface in a license-free band, one or more mobile beacons installed on objects to be tracked and modem providing gateway to the system from PC or other computers.

Mobile beacon's location is calculated based on a propagation delay of an ultrasonic pulses (Time-Of-Flight or TOF) between stationary and mobile beacons using trilateration algorithm.

The system can build the map of stationary beacons automatically. Thus, in simple cases, no additional manual data input or any manual distance measurements are required. This map formed once can be frozen and stored in modem's memory and the system becomes fully active within 7 to 10 seconds after the modem is powered.

Minimum configuration requirements to ensure optimal performance of the Marvelmind Indoor Navigation System:

- For 3D (X, Y, Z) tracking: an unobstructed line of sight (hearing) between a mobile beacon and 3 or more stationary beacons within 30 meters
- For 2D (X, Y) tracking - an unobstructed line of sight (hearing) between a mobile beacon and 2 or more stationary beacons within 30 meters

Key capabilities:

Parameter	Technical Specifications
Distance between beacons	- Reaches up to 50 meters in lab conditions. - Recommended distance is 30 meters (Transducer4 on the first beacon is looking straight at the Transducer4 on the second beacon, other transducers are switched off)
Coverage area	- Reaches up to 1000 m^2 with the Starter Set configurations - Coverage for larger territories is provided using submap – similar to cells in cellular networks
Location precision	- Absolute: 1–3% of the distance to the beacons - Differential precision: **±2 cm**
Location update rate	- 1/20Hz to 45Hz - Can be set manually via Dashboard software - Depends on the distance between mobile and stationary beacons (shorter distance—higher update rate) - Depends on the number of mobile beacons (update rate of 25Hz for 1 mobile beacon, 25Hz/2 for 2 mobile beacons, and 25Hz/3 for 3 mobile beacons etc.) - Depends on the radio profile (500kbps vs. 38kbps) - Slightly depends on the number of stationary beacons—dependence is not the same as for mobile beacons
Power supply	Internal: 1000mAh LiPo battery - Battery lifetime depends on the setting and mode of operation: chosen update rate, mobile vs. stationary, etc. - Stationary beacon with 16Hz update rate => up to 72h (tested). - Stationary beacon with 1Hz update rate => ~72h*16 => 1 month - Mobile beacon with 8Hz update rate – 12h (tested)
	External: micro USB – recommended for permanent use
Weight	Mobile beacon from the starter set: - 59 grams (including 1000mAh battery, housing and 50mm antenna) - 27 grams (bare board w/o battery)
Beacon size	Size: 55x55x33 mm (with 50mm antenna: 55x55x65mm)

3. Basics of the system

3.1 What's in the box

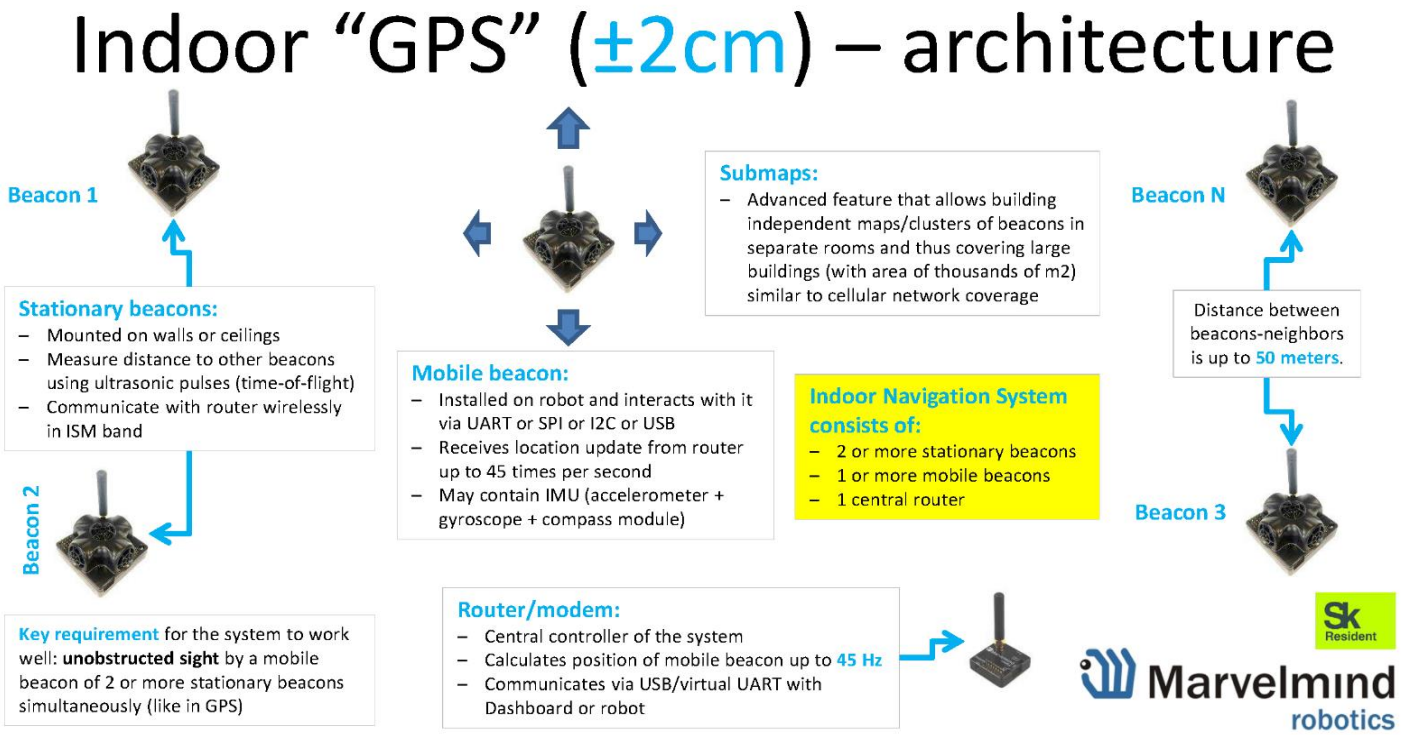
Starter Set:

- 4 x Stationary beacons
- 1 x Mobile beacon (aka "hedgehog")
- 1 x Modem/Router

* Starter set includes beacons without IMU. All pictures shown are for illustration purposes only. Actual product may vary due to product enhancement. Characteristics are the same or better unless stated otherwise.

3.2 Indoor Navigation System architecture

Marvelmind Indoor Navigation System provides high-precision (±2cm) indoor coordinates for autonomous robots and systems (“indoor GPS”). A brief description of the key elements of the system is given on the scheme below.



3.3 Indoor “GPS” System close-up and internal view

4. System elements

4.1 Stationary beacons

- Usually, mounted on the walls or ceilings above the robot with ultrasonic sensors facing down—to provide the most robust unobstructed ultrasonic signal coverage to the robot. However, for automatic landing and indoor navigation of copters, for example, it is recommended to install mobile beacon horizontally on the belly of the copter so that the beacon would be looking downwards

- The position and orientation of the beacons should be chosen in a way that provides maximum ultrasonic signal coverage. System efficacy strongly depends on the quality of ultrasonic signal received by stationary beacons
- Stationary beacons emit and receive ultrasound during the map configuration period. Once the map is formed and frozen, they only work as the receivers
- Stationary beacons have no exterior differences with regard to mobile beacons
- Inertial measurement unit (IMU) is not installed on the stationary beacons
- The mobile and stationary beacons can be easily interchanged by selecting corresponding option (except for IMU) during configuration in the Dashboard
- There are 433MHz and 915MHz versions available. A proprietary radio protocol is used for communication and synchronization. Other ISM bands are available upon request as well
- Stationary beacon can be equipped with full-size 165mm antenna (for 433 MHz), which provides more robust radio connection between modem and beacons

  * Full-size 165 mm antenna is optional.

4.2 Mobile beacon (“hedgehog”)

- The mobile and stationary beacons can be easily interchanged by selecting the option in the Dashboard

- The mobile beacons designed to be placed on a robotic vehicle, copter/drone, AGV, or helmet to trace its location. Formally speaking, location of the mobile beacon is traced—not the robot itself. Since the sizes and the location of the central point of the mobile beacon and the robot are different, the difference taken into account in the robot’s software (SW)

- It is recommended to place the mobile beacon horizontally to provide optimal ultrasonic coverage in the upper hemisphere

- Its sensors must not be covered with anything that can reduce the strength of ultrasonic signal. For example, the system won’t normally work, if one puts the mobile beacon in a plastic box

- The beacon’s coordinates are updated according to the rate set on the Dashboard

- The system may contain one or several mobile beacons. Current implementation relies on a time-division multiple access approach. Thus, if two mobile beacons are activated, they share the same system bandwidth. It means that, if the 16 Hz update rate is selected in the Dashboard and there are 2 mobile beacons in the system, each beacon’s location will be updated with the rate of 16Hz/2 ~ 8Hz. If there are 3 mobile beacons => 16Hz/3 ~ 5Hz, etc. Future SW implementation may contain different solution that will improve update rates in setups with multiple mobile beacons

- Location data is obtained either from the “hedgehog” via USB (virtual UART), UART, SPI, or from the modem/router via USB (virtual UART). More information on interfaces can be found here

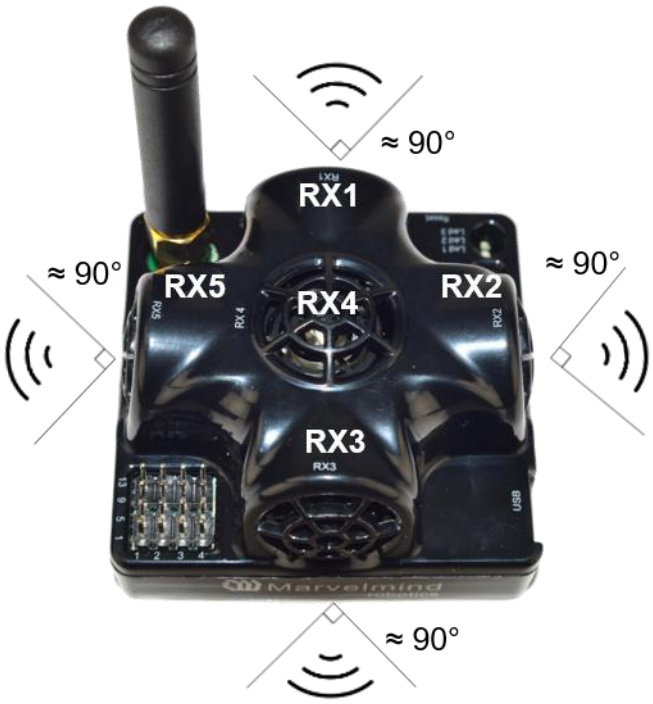
- Data from the beacon sent in a streaming format identical to that of GPS (NMEA 0183)

- There are 433MHz and 915MHz versions available. Proprietary radio protocol is used for communication and synchronization

- The “hedgehog” has been successfully integrated with Windows PC, Linux machines, Raspberry Pi, Arduino boards, Intel boards, etc.

4.3 Ultrasonic coverage

Each transducer on the beacons has ~90° of ultrasonic coverage



4.4 Modem/router

- Modem is the central controller of the system. It must be powered at all time when the Navigation System is working. It recommended to use an active USB hub for that purpose or even a regular cellular phone USB power supply. A USB power bank can also be used
- The modem is also used to set up the system, monitor it, and interact with the Dashboard
- It can be placed anywhere within radio coverage for permanent radio connection with all beacons—usually in the radius of up to 100 meters with antennas from the Starter Set.
- Radio coverage further extended to a few hundred meters by using a lower bitrate of 38kbps and full-size (165mm for a 433MHz band) antennas, which have been tested to provide up to 400 m in ideal conditions
- There are 433MHz and 915MHz versions available
- A proprietary radio protocol used for communication and synchronization between modem and beacons

4.5 Charging beacons and other details

- The Beacon has 5 sensors (transducers): RX1, RX2, RX3, RX4, and RX5
- Charging occurs automatically every time a USB charger is attached to the board. LED 1 is active and lights red
- It takes 1–2 hours to fully charge the board's battery
- If you plan to use a charger for permanent powering of the beacon, make sure that the power source is not noisy (The USB +5V is not noisy). The performance can be monitored by using:

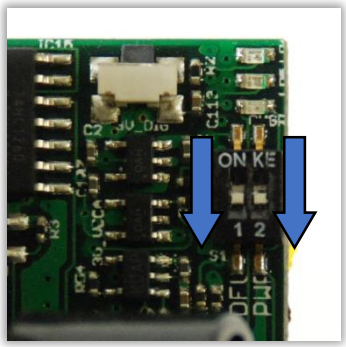
  Dashboard => View => Oscilloscope.

  Read the paragraph Using Oscilloscope

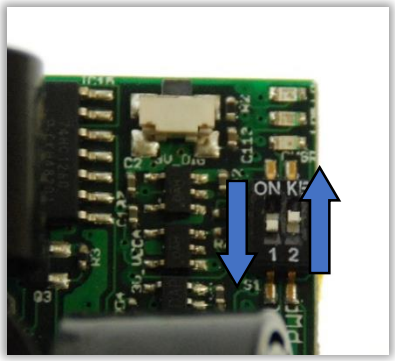
- When the board is charged and turned on, LED 2 will blink every few seconds, if to press RESET button and modem is active. If modem is not active or works on a different radio channel, the beacon automatically goes into sleep mode after 1 minute.

4.6 DIP switch modes

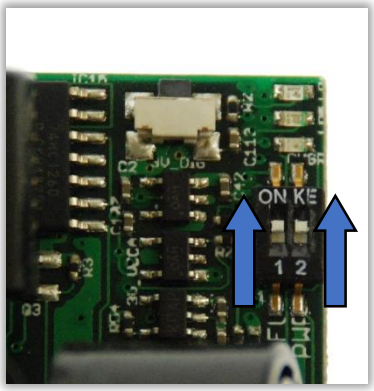
1) ***Power* = OFF**, ***DFU* = OFF**: Charging is possible; beacon disconnected from internal battery. This mode recommended, if you want to keep the battery fully charged for a long time and to store the beacon on the shelf



2) ***Power* = ON**, ***DFU* = OFF (pictured below)**: Normal working mode for the beacon. The beacon is fully powered and will wake up every a few seconds to monitor radio signals from the modem. Power consumption is still minimal, if the beacon sleeps; the battery can last for many weeks or months. It is recommended the beacon be kept in this mode and the DIP switch not be touched at all, unless you plan to store the beacon on the shelf. If that's the case, then mode 1 is recommended



3) ***Power* = ON**, ***DFU* = ON**: DFU programming mode. It is used for the initial SW uploading or when the HEX SW cannot be uploaded from the Dashboard



5. Setting up the system

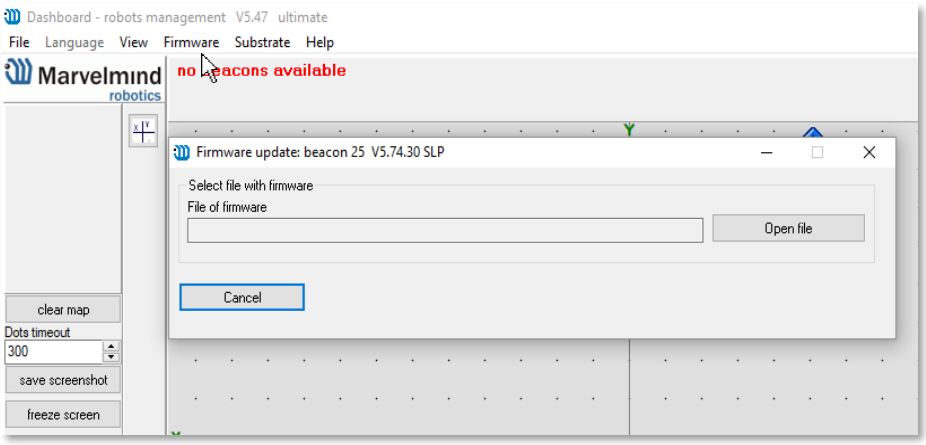
5.1 First setup of your device

The steps below describe the very first time you set up of the system:

- Unpack the system. Watch the help video: https://youtu.be/sOce7B2_6Sk
- Check that your boards are charged; see that all switches on the beacons are in the correct position (***Power* = ON; *DFU* = OFF**). See the paragraph DIP switch modes
- Press the **RESET** button on each beacon. If LED 2 is not blinking, it means your board is turned off or discharged. Check the position of the DIP switch again or charge the beacon via USB

5.2 HEX programming

- After charging boards, download the latest stable SW package from https://marvelmind.com/pics/marvelmind_SW.zip
- Run the Dashboard and update the SW for all beacons and modem using **Dashboard => Firmware => Choose the file => Program**



- If you see the message "**Not found modem connection to computer through USB**" in the Dashboard or your PC does not recognize beacons/modem, it usually means that the STM32 driver is not installed. To install the driver, download it with link at top window in the Dashboard and run the installation file, then click on the link under and install the driver

  Ensure that:

  (a) You are programming the modem's SW to the modem and the beacon's SW to the beacon

  (b) You are using SW for 4.9, if you have HW v4.9; and you have the SW from the same SW pack, i.e., the Dashboard SW, modem SW, and beacon SW must be from the same SW pack. Don't mix SW releases

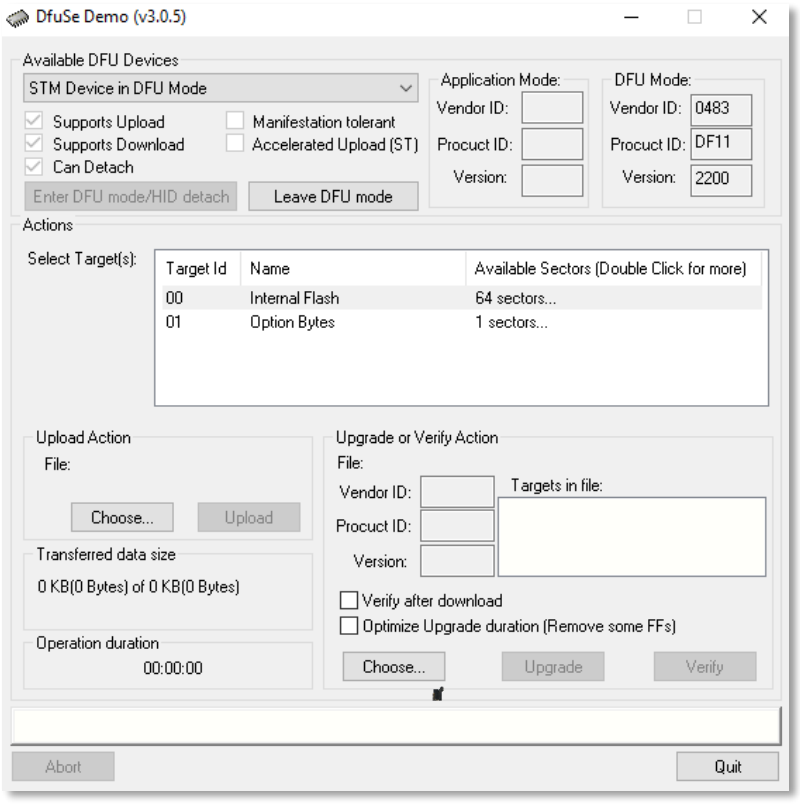
5.3 DFU Programming

DFU programming or SW uploading is used when HEX SW uploading in the Dashboard cannot be used. For example, when you are updating from a very old SW version or when the SW includes major changes to the system and the only possible way to update the SW is via DFU programming

- After the DFU SW upgrade, futures SW upgrades can be done in a regular manner via the Dashboard
- To start programming, move the beacon's DIP switch to the DFU programming mode, as described in the paragraph on DIP switch modes
- Download the latest SW package, unzip it, and select the proper version of the SW for your HW and for your frequency variant. Remember that for DFU programming, you should use DFU SW (DfuSe), not Dashboard's .hex file
- Download DfuSe
- Here you will find different versions of DfuSe. v3.0.4 or v3.0.5, whichever works the best for your Windows: DfuSe v3.0.4 or DfuSe v.3.0.5

DFU Programming:

- Put DIP switch into ***Power*** **= ON**, ***DFU*** **= ON**
- Connect the beacon via USB to your PC
- Run DfuSe
- Press the **RESET** button on your beacon
- In the upper left corner of the DfuSe program, you will see a device connected in the DFU mode
- Choose the DFU driver (file) for the beacon



- Click the **UPGRADE** button

- After a couple of seconds, the DFU will be uploaded to the beacon. Make sure it actually takes 1–3 seconds and does not happen immediately. Otherwise, the SW has not been really uploaded. If the DFU appears to upload immediately, check the "Choose" button you used or change the version of DfuSe SW you selected
- Move the DIP switch into ***Power* = ON**, ***DFU* = OFF**
- Start the Dashboard and press the **RESET** button on the beacon
- Check SW on the beacon afterwards
- Everything should be OK with SW now. DFU programming is complete

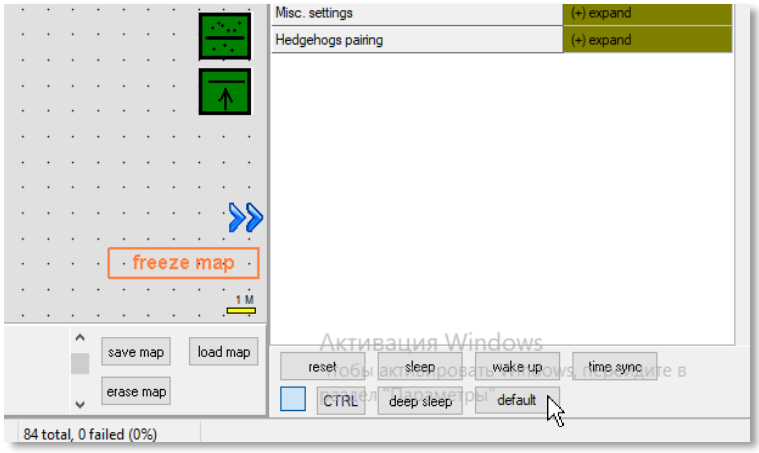
- Follow the same scenario for the modem:
  - Here is the link for the modem DFU programming. The steps are similar to those for beacon DFU programming
  - After uploading DFU driver by DfuSe short circuit holes temporarily as shown on the picture (for v4.9) press **UPGRADE** button in the DfuSe program
  - After a couple of seconds, the DFU will be uploaded to the modem. Make sure it actually takes 1-3 seconds and does not happen immediately. Otherwise, the SW has not really uploaded. If the DFU appears to upload immediately, check the "Choose" button you used or change the version of DfuSe SW to a different one
  - Disconnect the short circuit
  - Start the Dashboard and press **RESET** button

- If you experience difficulties in DFU programming, please check and do the following:
  - Change your operation system (from Windows 10 to Windows 7 or vice versa)
  - Install a different DfuSe version (whichever works best with your Windows)

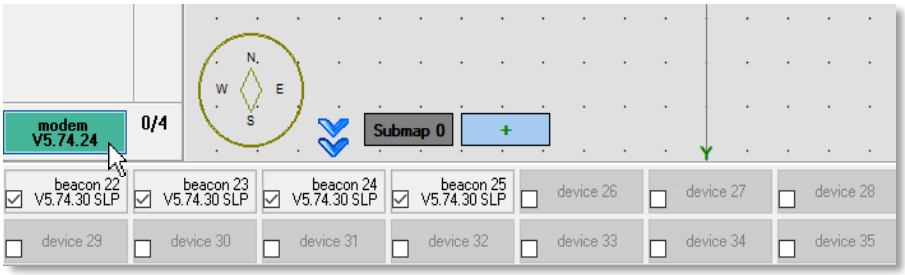
5.4 Setup the Dashboard SW

If you have uploaded the latest firmware for all of the boards, you can start to activate the system:

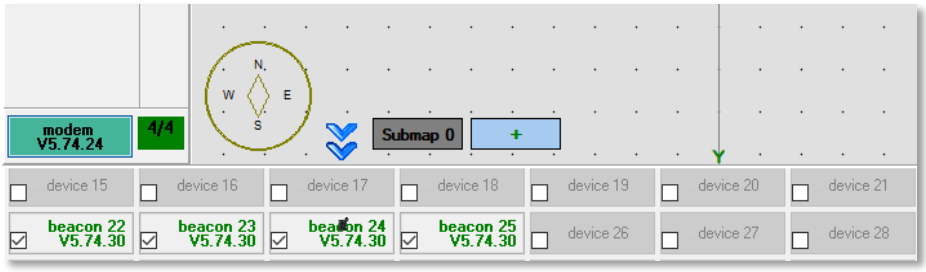
- While the beacon or modem is connected to the Dashboard, click the **DEFAULT** button on the Dashboard to upload the default settings



- Write down the beacon's address for future use or change the address at your convenience as shown here
- Press the **RESET** button on your beacons and modem after programming
- After programming devices with the latest software, the modem and beacons are ready for use
- Place the stationary beacons on the walls vertically in a way that will provide optimal ultrasonic coverage. It is recommended that you start with a simple 4m x6m room or so and place the stationary beacons on the opposite walls at a height of 1.85m (default). After familiarizing yourself with the system, more complex configurations can be made. The help video can be found here
- Connect the modem/router via USB to a Windows PC with the Dashboard installed
- Run the Dashboard. In the left corner of the Dashboard, the modem should be shown as connected

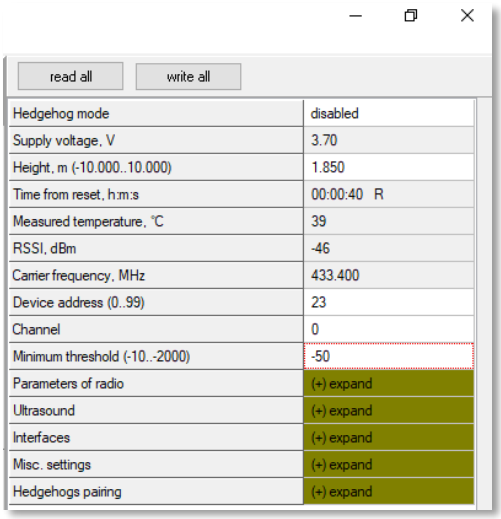


- Wake up all beacons by clicking on the buttons in the Dashboard on the panel
- It may take up to 7-10 seconds for the beacons to wake up

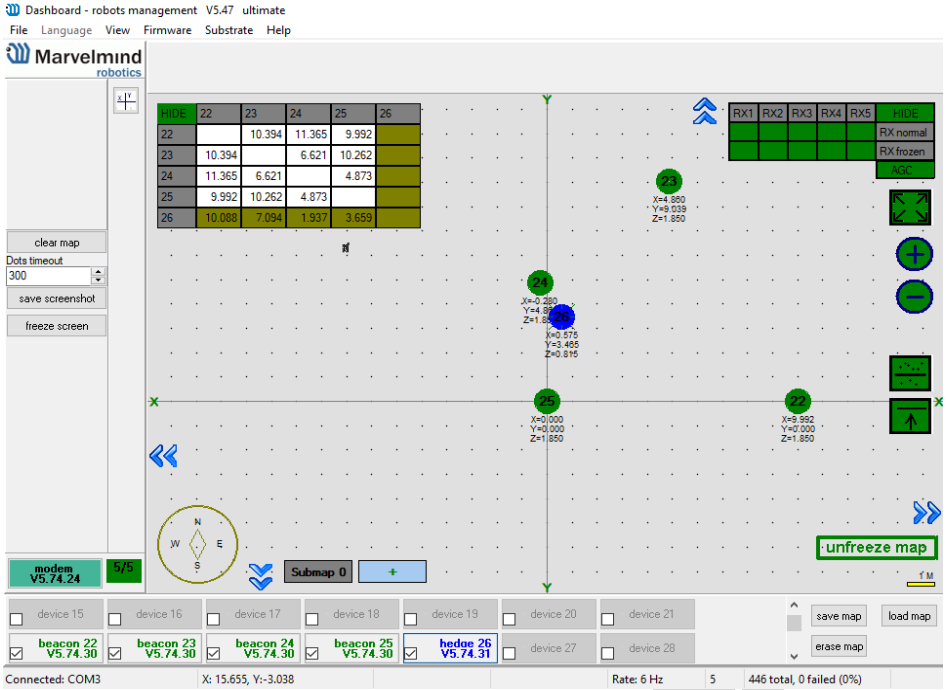


- Notice, that if the modem is not active and is not powered, the beacons will go into sleep mode automatically after 1 minute

- The system may run the frequency search, if it is the very first time you are waking up the beacons. If this step does not work, disconnect the modem and connect that beacon again via USB. Press the DEFAULT button in the Dashboard and the Read All button to make sure that the radio settings are really the default ones
- Compare the radio settings on the modem and the radio settings on the beacon. They must be the same
- Now you can check the height position of the beacons, RSSI, radio channel, threshold, etc. on the panel on the right corner of the Dashboard



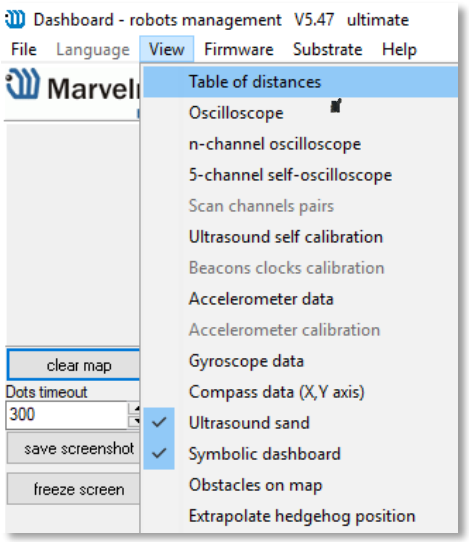
- It is possible to manage 30 beacons simultaneously. In current version one modem supports 30 beacons. If you do not see some of your connected beacons on the map, you may need to scroll to find their addresses
- Double click on the device both to put it into sleep mode and to wake it up
- The map will form and zoom in automatically
- If the map does not form well, check the table of distances in the left corner of the Dashboard. The cells must be colored in white; it means the distances between stationary beacons are measured correctly



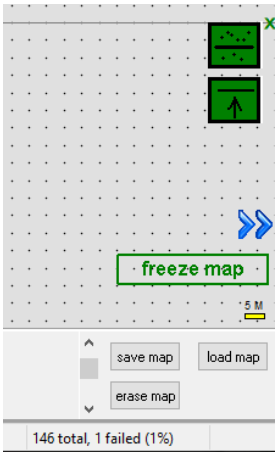
- If you see in the table some empty cells or marked yellow/red, it is an indication that distances between Some beacons are measured inconsistently or not

measured at all. Try to re-position them because usually there is an obstruction of some sort in the between the beacons. It also may be different height of beacons' positon. Reset all these beacons.

- Use **View => Table of distances** to monitor the measured distances between beacons

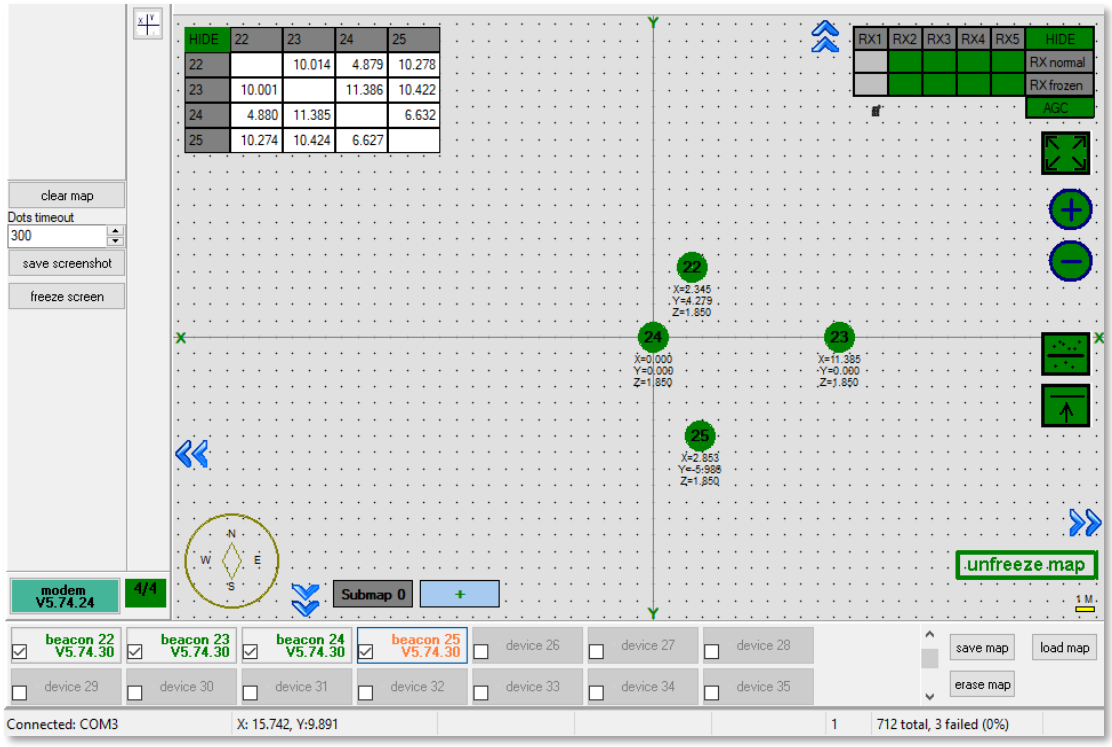


- Freeze the map by clicking the button. Stationary beacons will stop measuring relative distances and will be ready to measure distance from the mobile beacon(s)



- Turn on and wake up the mobile beacon following the same steps as with the stationary beacon: https://youtu.be/A4aRsjH2-_E
- If you see on the devices' panel in the Dashboard that the beacon is colored orange, it means there are some differences in some of the settings between beacons. For example, some sensors may be off or some ultrasonic or radio settings may be different. You can change the settings for sensors manually by clicking on the panel on the upper right corner of the Dashboard to change the cells from gray to green to turn on sensor. It is recommended that the default settings on all beacons and the modem be used if this is your first time using the system
- After you freeze the map of stationary beacons, wake up the mobile beacon. After it wakes up, it will be traceable in 5-7 seconds
- The system is now fully operational

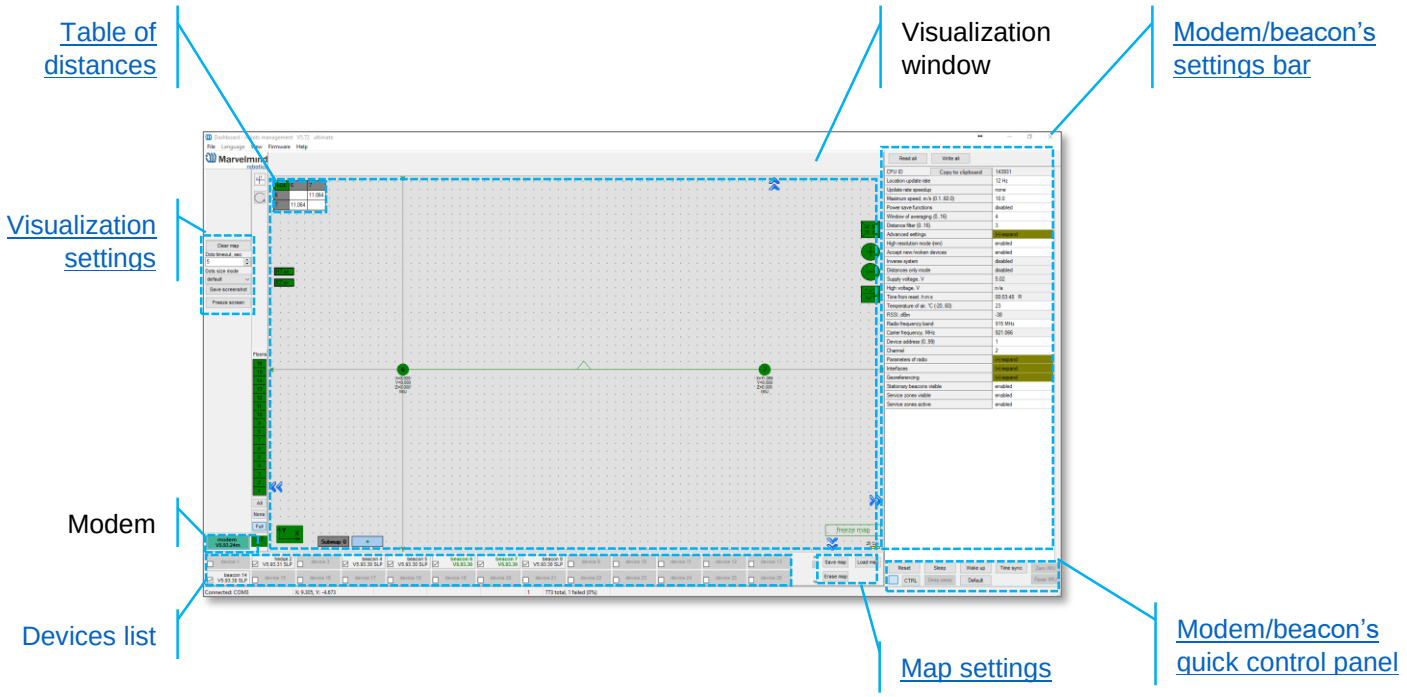
- In the dashboard, you can upload a picture / map of your room. You can use different picture for every floor. Go to **Loading the floorplan**



6. Dashboard menu and parameters

6.1 Dashboard general view

- This picture shows the Dashboard's general interface and items' positions



6.2 Table of distances

Table of distances shows measured distance between all the beacons. The map and its graphical visualization depends on distances. So, that is very important part of the system.

There are two ways of measuring:

1) Measuring by ultrasound (automatic)
2) Measuring by user (manual)

*In noisy cases and cases with a long distance it is better to use manual input

1) Measuring by ultrasound:

- In most cases, the system builds the table of distances automatically. If everything is good, there would be figures in cells, they would be changing a little; cells color would be white

HIDE	5	22	66	77
5		7.144	12.389	10.101
22	7.144		10.122	12.151
66	12.389	10.122		6.879
77	10.101	12.151	6.879	

- If color differs, check the colors' definitions (next page) and solve the problem
- Freeze the map only if cells are white

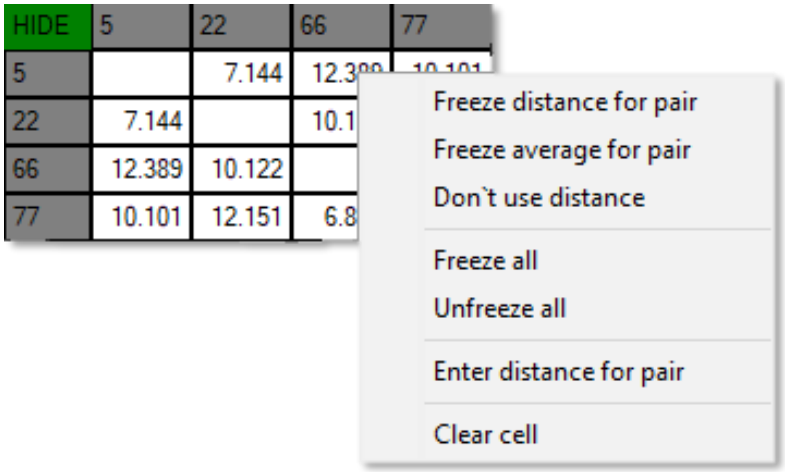
2) Measuring by user:

- Use manual input if table of distances didn't build. It may happen if environment is very noisy, or distances are very huge
- In that case, cells' color would be green
- Be careful with figures because a small mistake in that values will cause big mistakes in location

How to freeze/enter distance manually:

Step 1. Open the Dashboard. You will see the table of distances

Step 2. Use right mouse click on cell you want to freeze/enter. Additional menu will open. There you can control the table of distances. Choose **Freeze distance for pair** to freeze it



Step 3. Now, cells are frozen. That values would not change until you unfreeze it. Even if beacons had been moved, distance would stay. Be careful with frozen cells because a small mistake can cause a huge impact on your tracking

HIDE	6	22	66	77
6		8.000	27.378	5.054
22	8.000		28.688	18.739
66	33.772	29.794		18.741
77	17.315	7.585	3.522	

Step 4. Repeat for all cells

HIDE	6	22	66	77
6		8.000	4.200	11.400
22	8.000		13.100	6.500
66	4.200	13.100		10.800
77	11.400	6.500	10.800	

- White means that everything is good, you can freeze the map

- Yellow means that something seems to be wrong, check distances and sensors before freezing

- Red means some critical misses, **DO NOT freeze the map**. Manually measure and enter distances

- Green means frozen distance, you can freeze the map, but be careful with values

6.3 Devices list

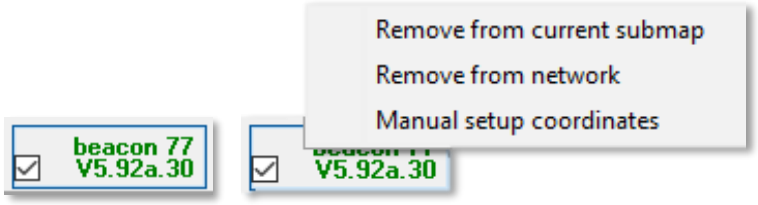
Devices list contains information about all the beacons in the system. It also allows to search, add and delete it.

Devices in this section are divided into two types:

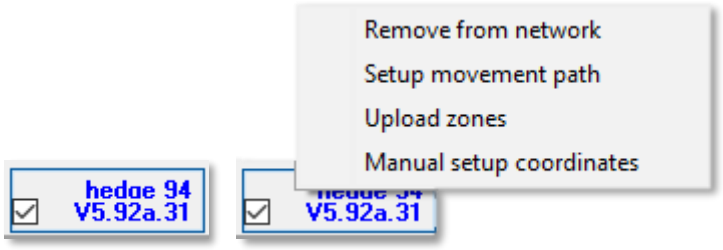
1) Stationary beacon (beacon)
2) Mobile beacon (hedge)

- Devices list allows user to manage devices
- Use double click to send beacon asleep

1) Stationary beacon (beacon)
    - Press RMB and additional menu will open
    - There you can:
        - Remove beacon from current submap
        - Remove beacon from the whole network
        - Manually setup coordinates (x, y, z)



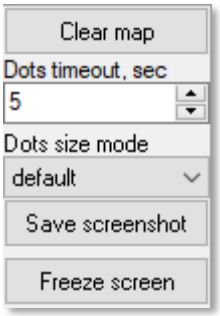
2) Mobile beacon (hedge)
    - Press RMB and additional menu will open
    - There you can:
        - Remove beacon from the network
        - Setup movement path
        - Upload zones (allowed and denied)
        - Manually setup coordinates (x, y, z)



6.4 Visualization settings

Visualization settings window has some functions to control visualization process:

- Clear map – clear all movement path
- Dots timeout – time of path's existence (Video: Help: Dots timeout)
- Dots size mode – size of dots
- Save screenshot – files saves to **Dashboard's folder/screenshots**
- Freeze screen – The map freeze, no updates of the path



6.5 Map settings

Map settings helps to work with the map. Can do following things:

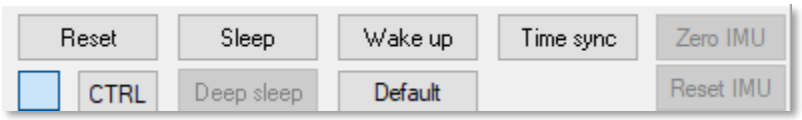
- Save map – saves map as *.ini* file into **Dashboard folder/maps**
- Load map – loads map from *.ini* format file
- Erase map – erases map and clears it

6.6 Modem/beacon’s quick control panel

Control panel allows user to interact with devices. It can work with one device, or with all devices in the system.

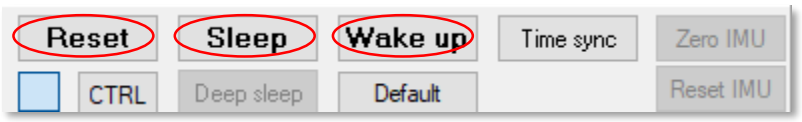
List of functions:

Reset – Resets device
Sleep – Send device asleep (battery economy mode)
Wake up – Wakes up device (from sleeping mode)
Default – Drops all device’s settings to factory default
Time sync – Sends time from your PC to hedgehog (for stream it out via UART)



Additional Ctrl feature:

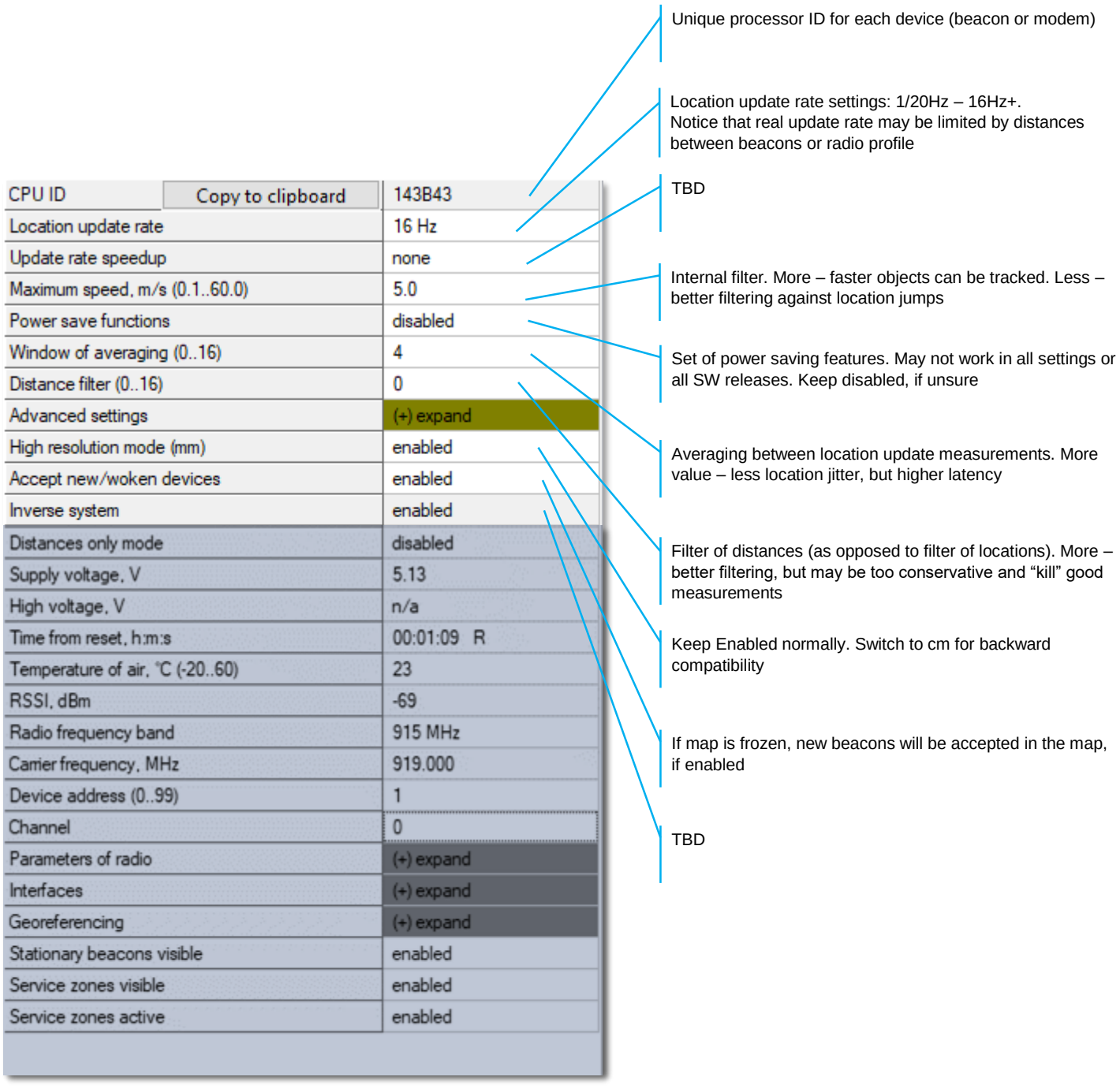
To apply action to all beacons in the system, use **Ctrl + left mouse click** on button
*Applicable only for buttons which turns **bold** while Ctrl is pressed

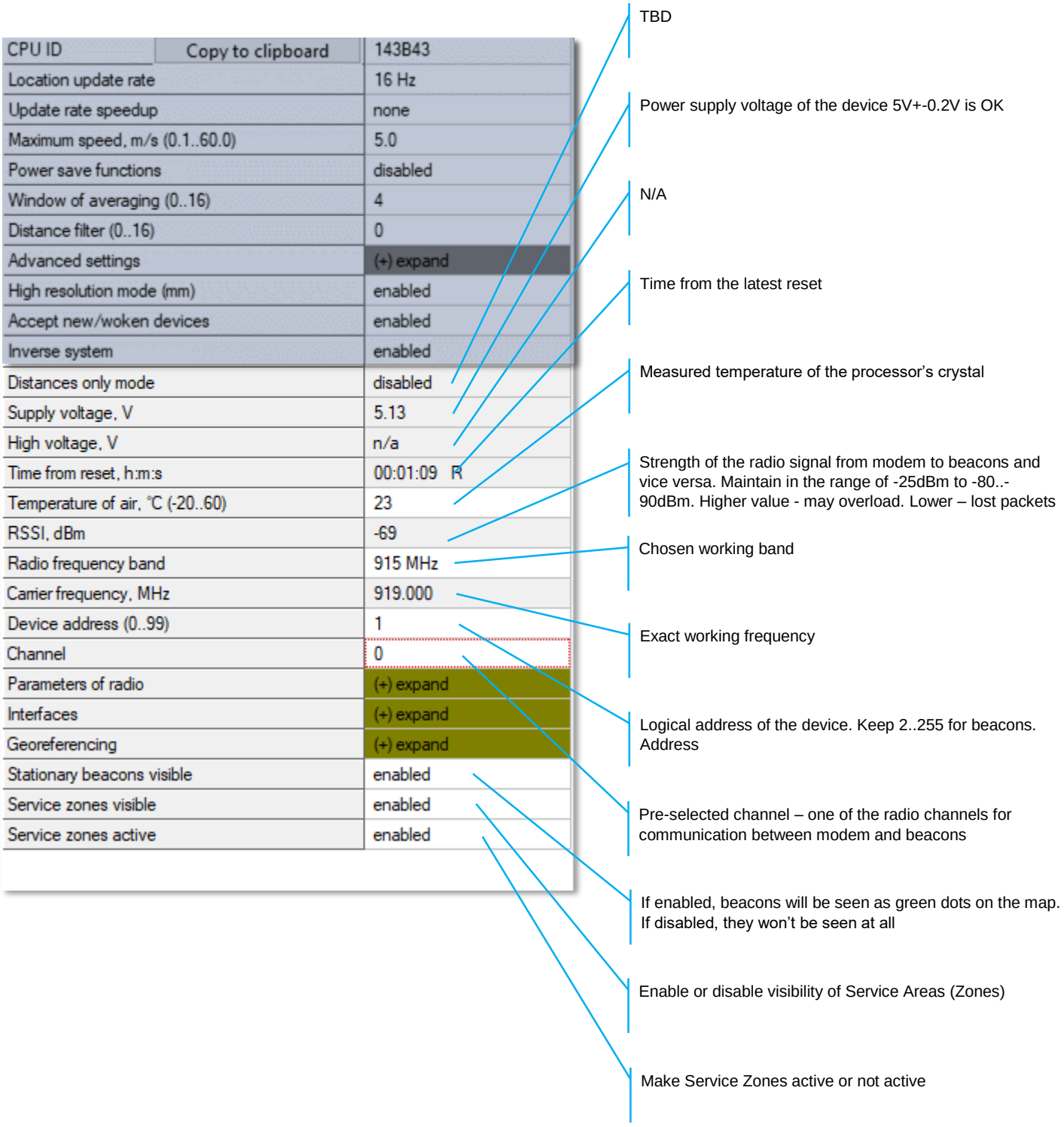


6.7 Modem’s settings

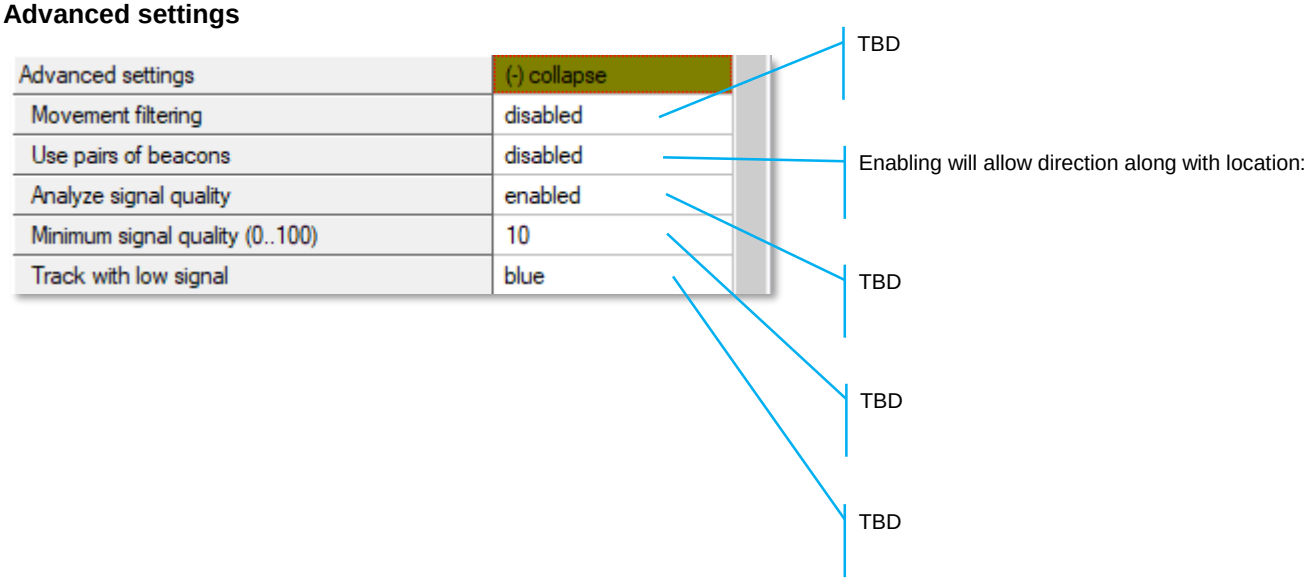
This bar allows user to adjust devices very precisely. It contains a lot of parameters for advanced usage

Modem’s settings

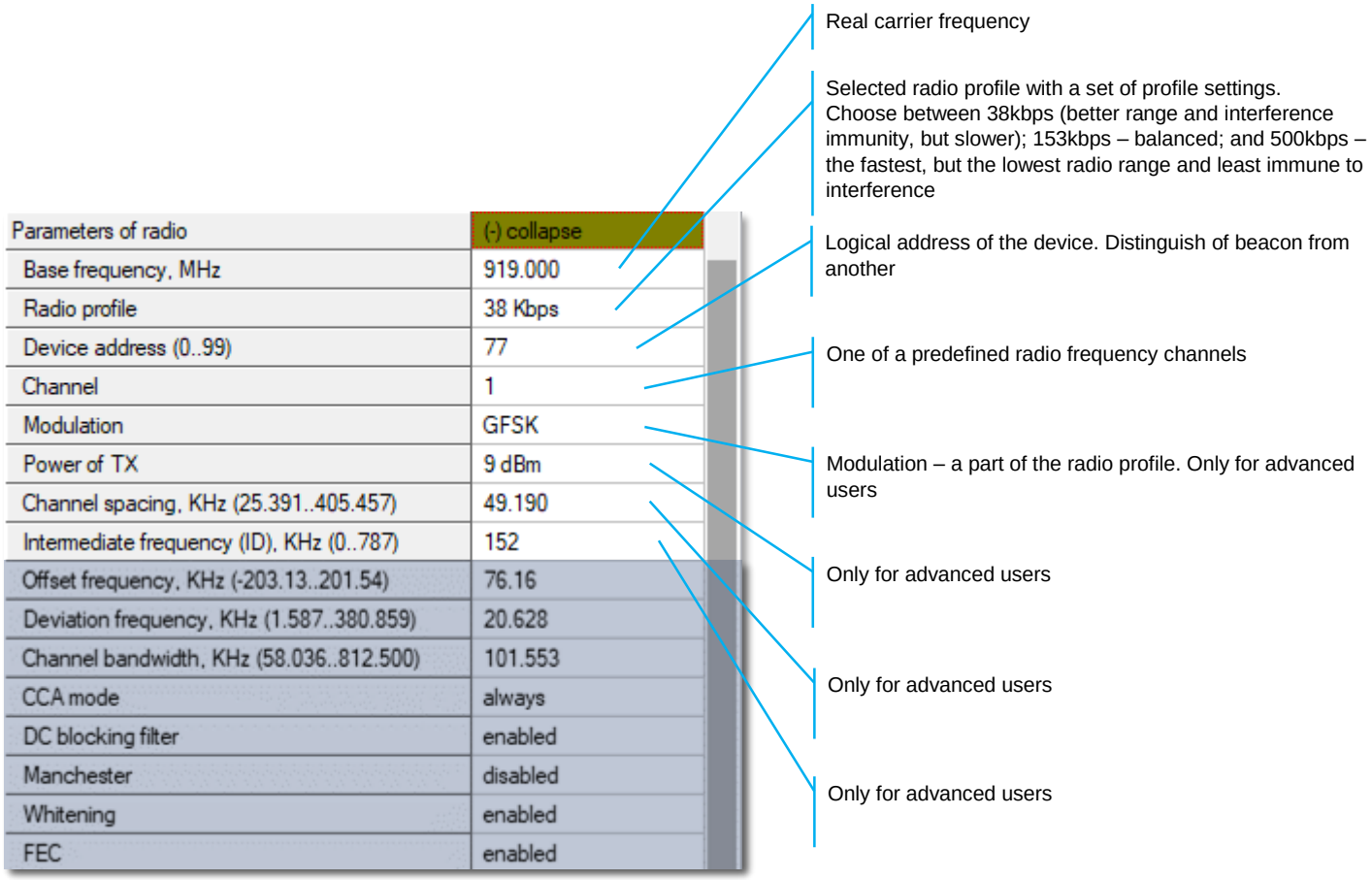


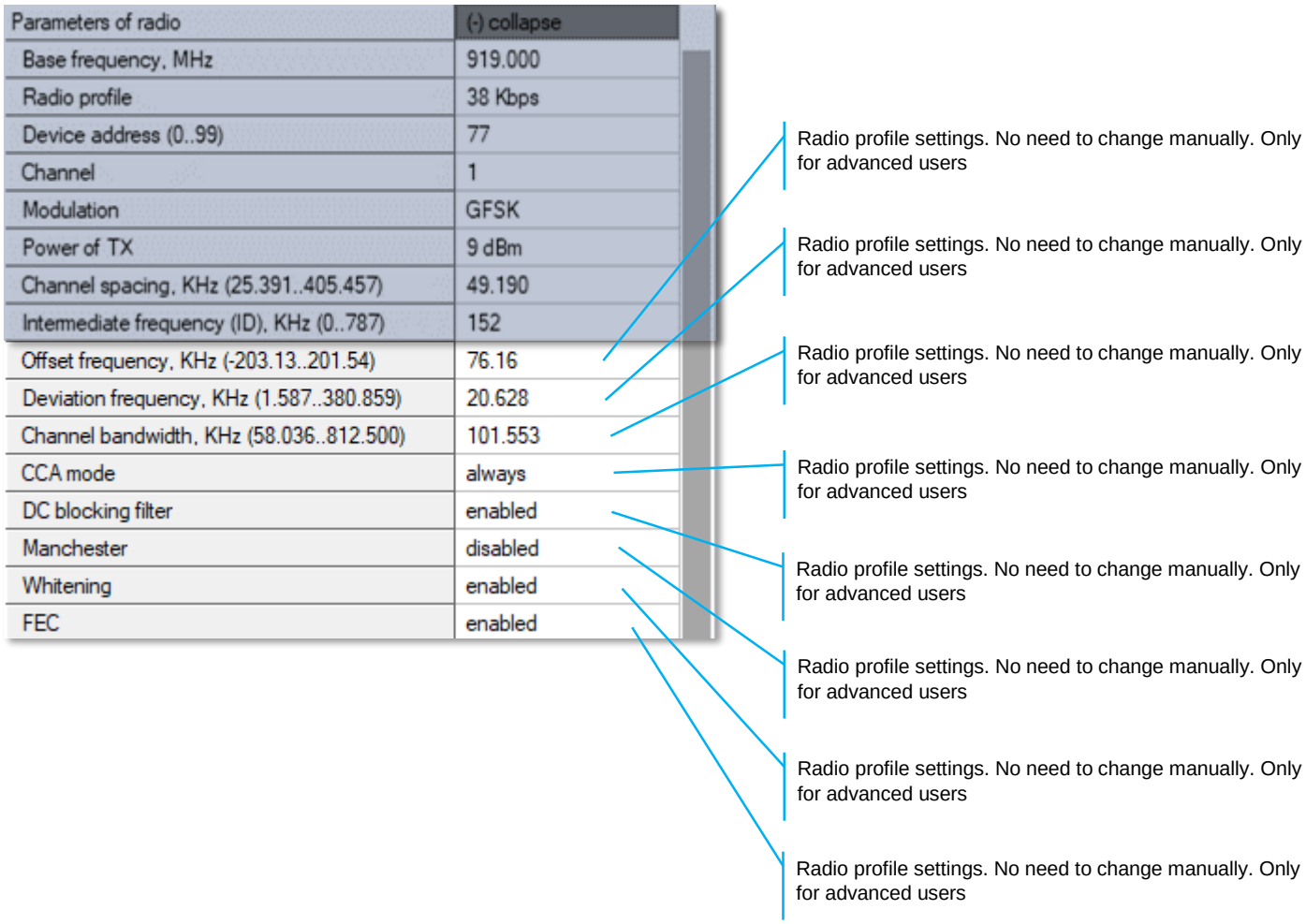

CPU ID
Copy to clipboard
143B43
Location update rate
16 Hz
Update rate speedup
none
Maximum speed, m/s (0.1..60.0)
5.0
Power save functions
disabled
Window of averaging (0..16)
4
Distance filter (0..16)
0
Advanced settings
(+) expand
High resolution mode (mm)
enabled
Accept new/woken devices
enabled
Inverse system
enabled
Distances only mode
disabled
Supply voltage, V
5.13
High voltage, V
n/a
Time from reset, h:m:s
00:01:09 R
Temperature of air, °C (-20..60)
23
RSSI, dBm
-69
Radio frequency band
915 MHz
Carrier frequency, MHz
919.000
Device address (0..99)
1
Channel
0
Parameters of radio
(+) expand
Interfaces
(+) expand
Georeferencing
(+) expand
Stationary beacons visible
enabled
Service zones visible
enabled
Service zones active
enabled
TBD
Power supply voltage of the device 5V+-0.2V is OK
N/A
Time from the latest reset
Measured temperature of the processor's crystal
Strength of the radio signal from modem to beacons and vice versa. Maintain in the range of -25dBm to -80..-90dBm. Higher value - may overload. Lower – lost packets
Chosen working band
Exact working frequency
Logical address of the device. Keep 2..255 for beacons. Address
Pre-selected channel – one of the radio channels for communication between modem and beacons
If enabled, beacons will be seen as green dots on the map. If disabled, they won't be seen at all
Enable or disable visibility of Service Areas (Zones)
Make Service Zones active or not active

Advanced settings

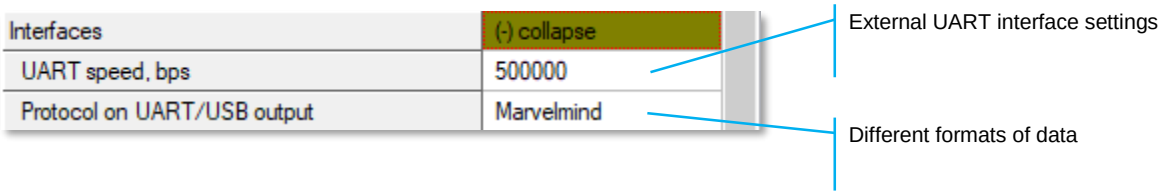


Parameters of radio

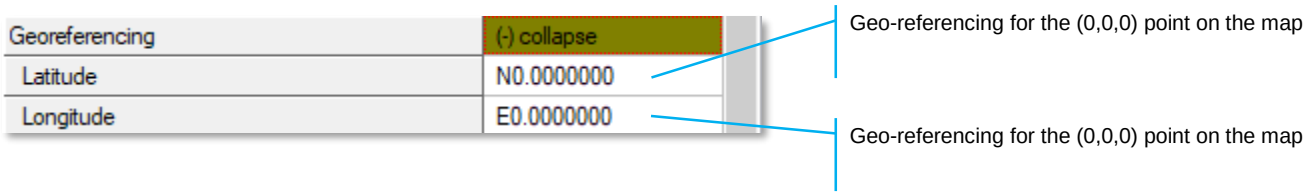



Parameters of radio
(-) collapse
Base frequency, MHz
919.000
Radio profile
38 Kbps
Device address (0..99)
77
Channel
1
Modulation
GFSK
Power of TX
9 dBm
Channel spacing, KHz (25.391..405.457)
49.190
Intermediate frequency (ID), KHz (0..787)
152
Offset frequency, KHz (-203.13..201.54)
76.16
Deviation frequency, KHz (1.587..380.859)
20.628
Channel bandwidth, KHz (58.036..812.500)
101.553
CCA mode
always
DC blocking filter
enabled
Manchester
disabled
Whitening
enabled
FEC
enabled
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users

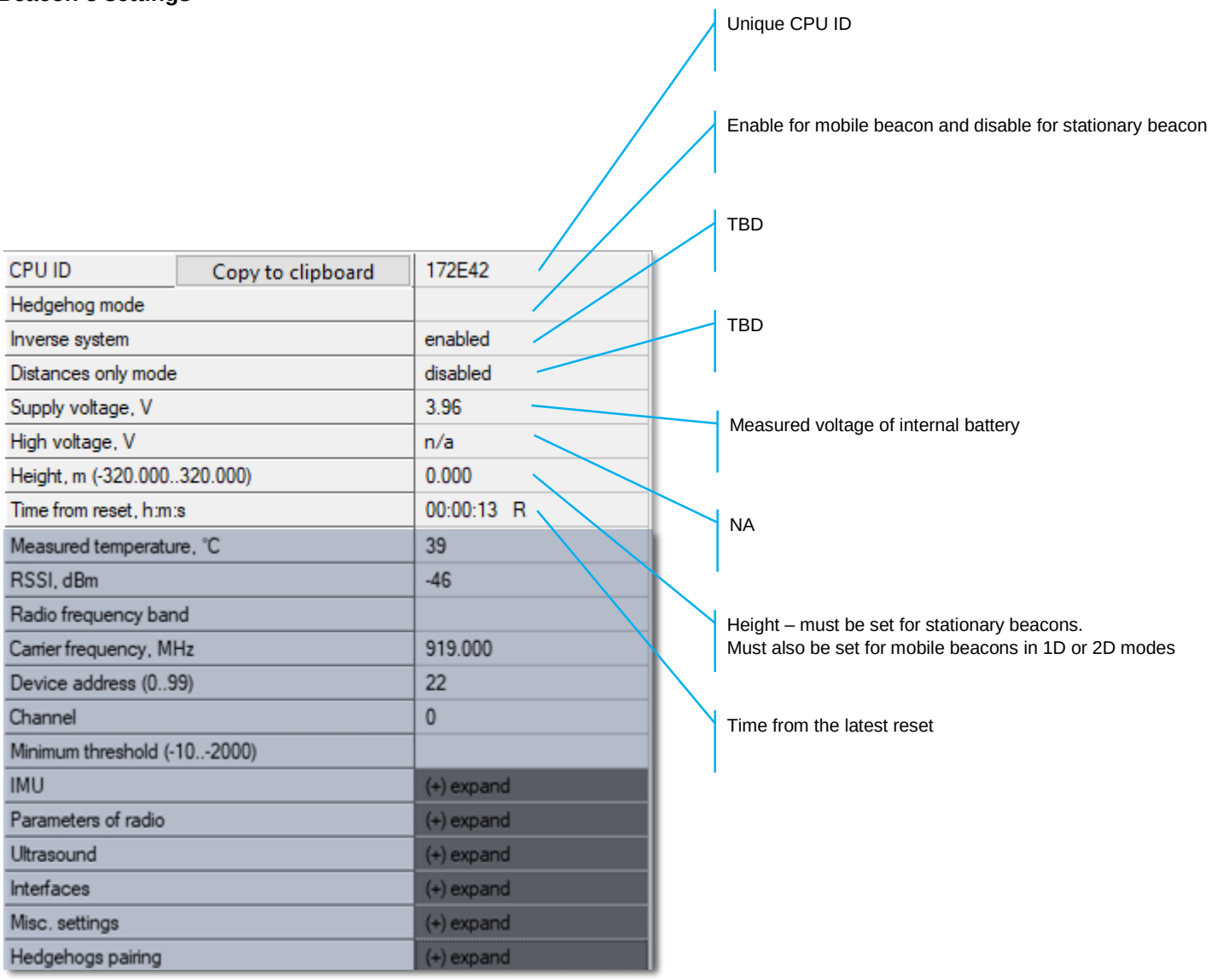
Interfaces

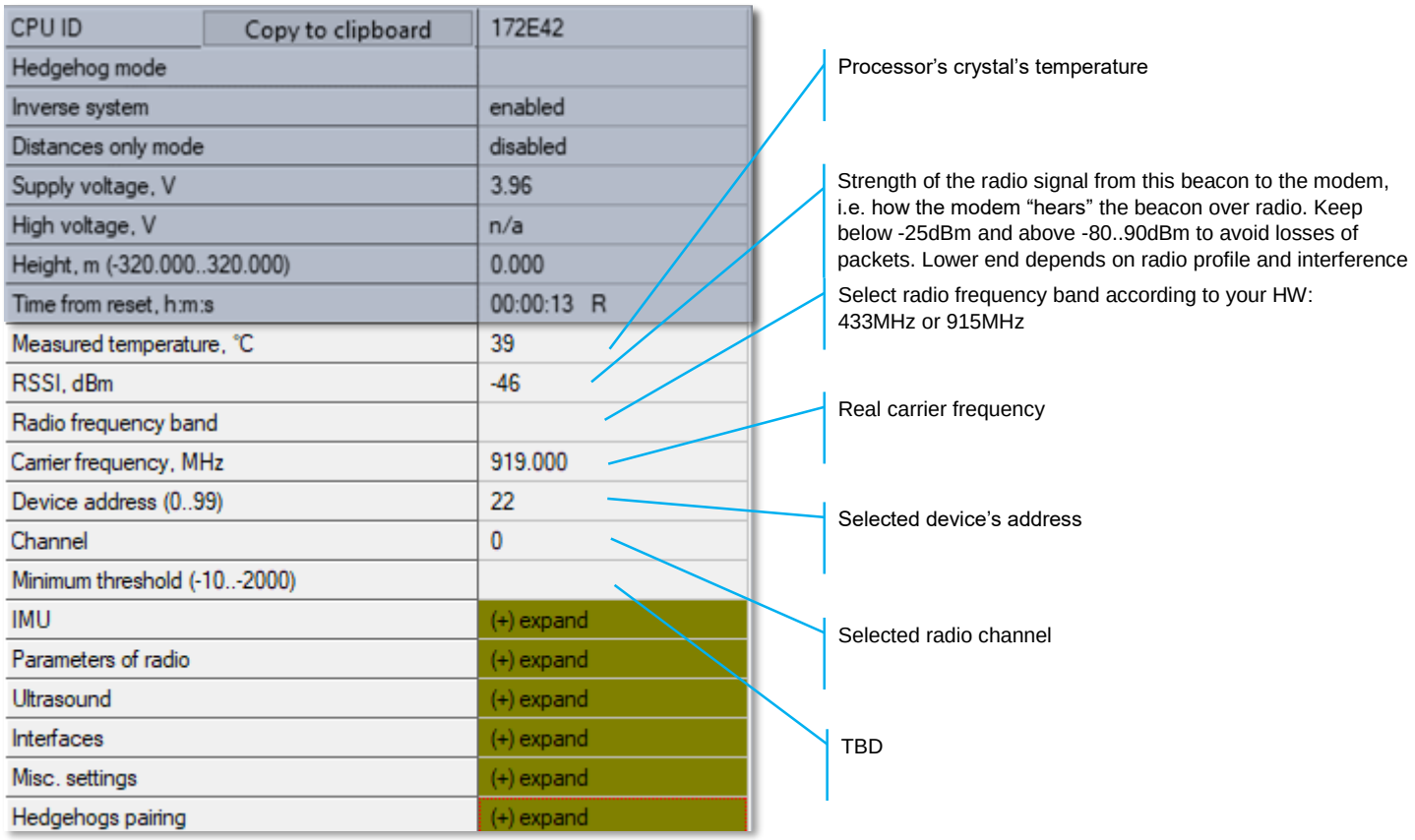

Interfaces
(-) collapse
UART speed, bps
500000
Protocol on UART/USB output
Marvelmind
External UART interface settings
Different formats of data

Georeferencing

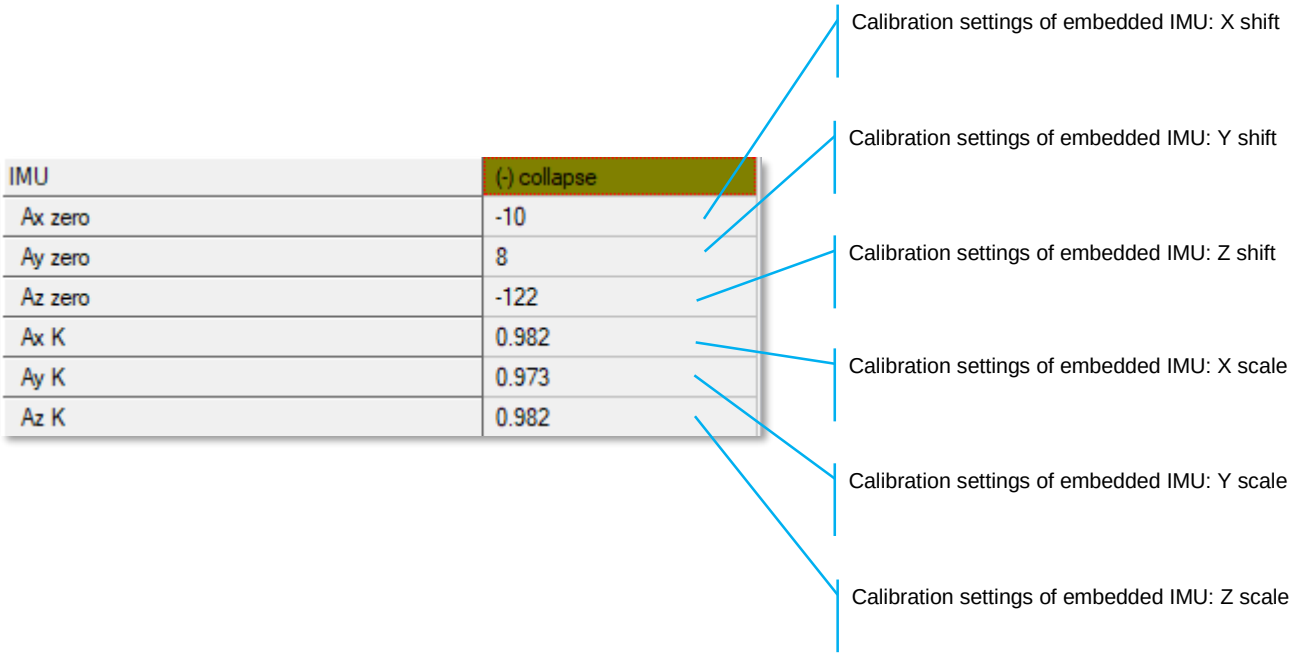


Beacon’s settings

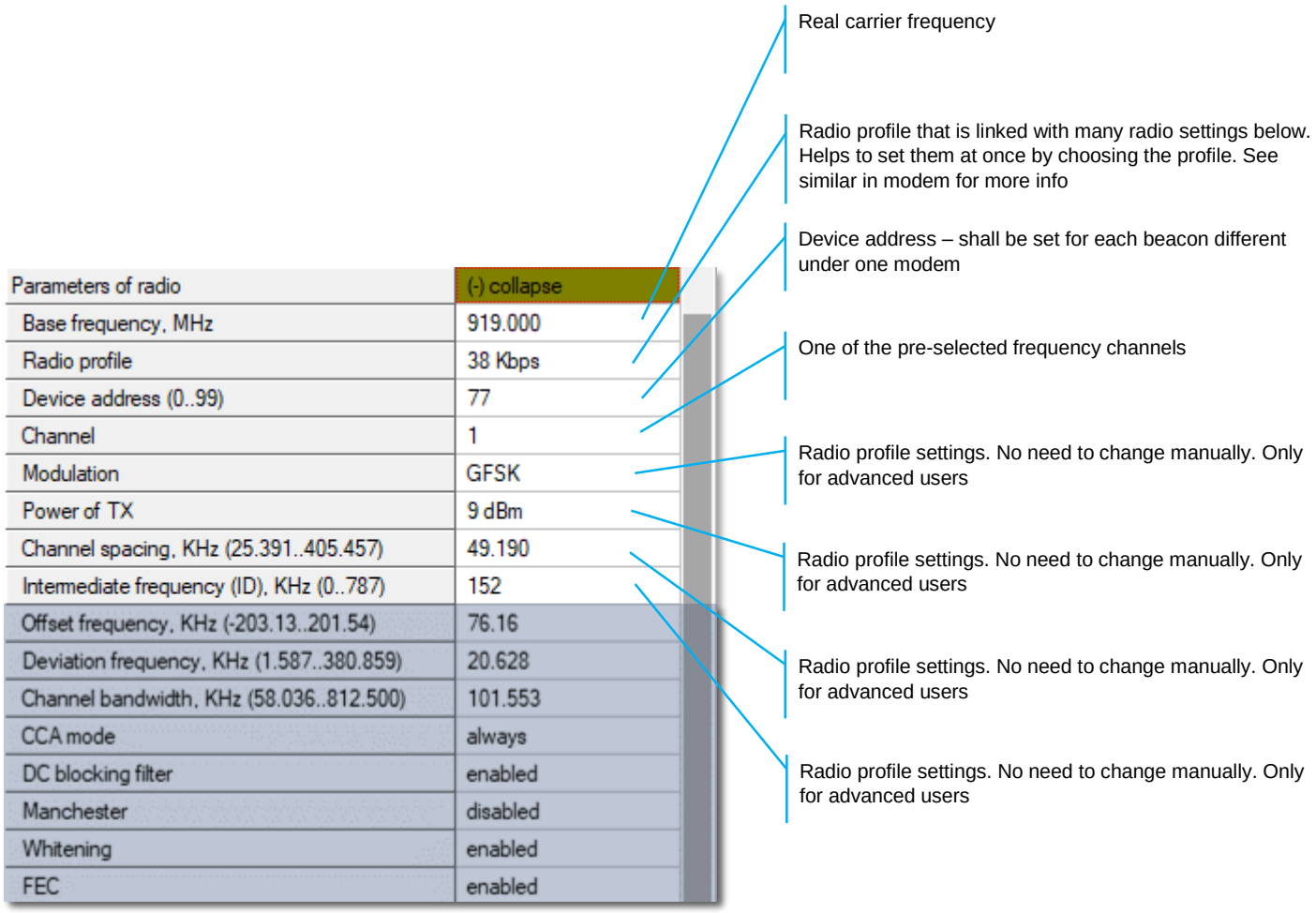


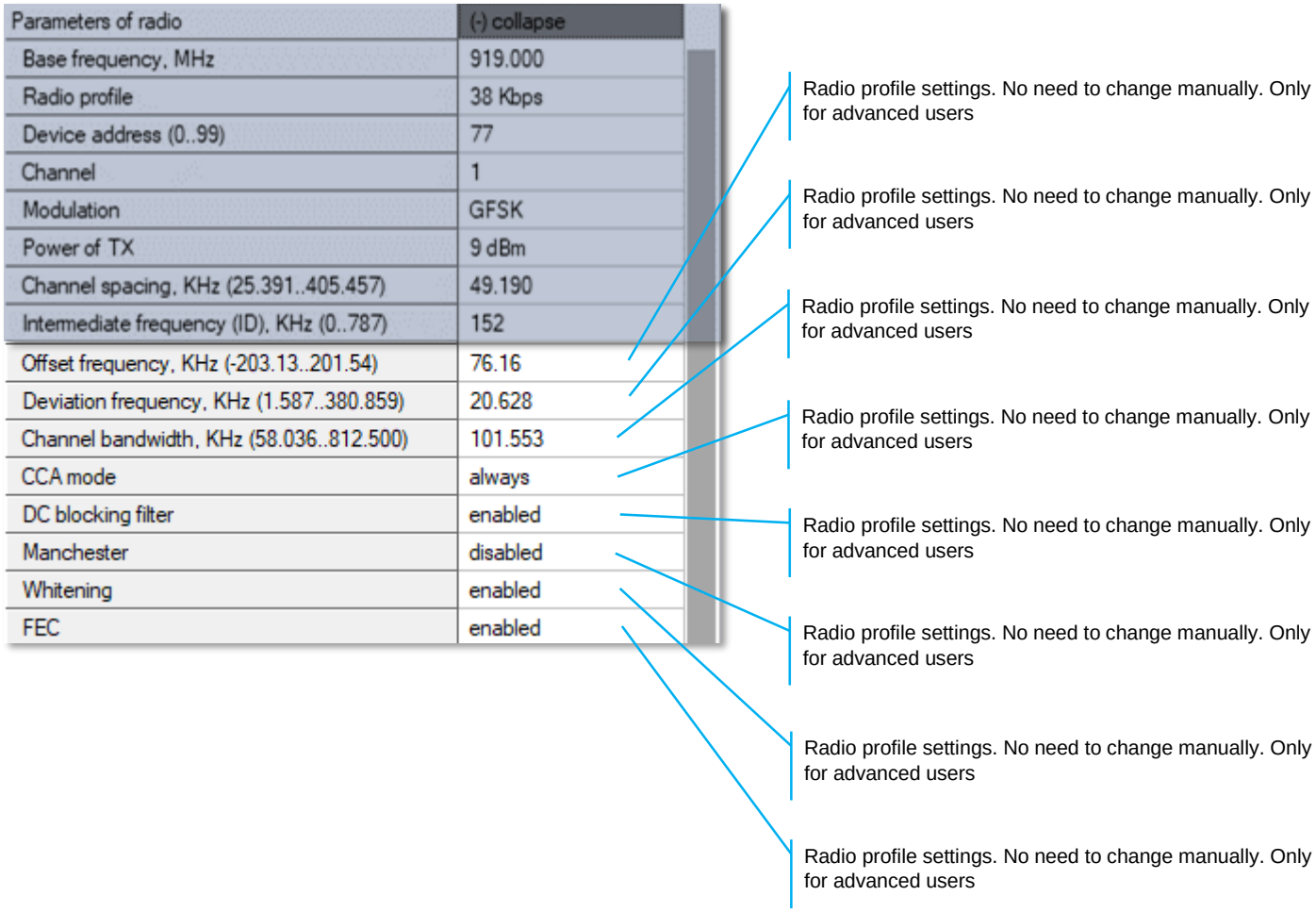

CPU ID
Copy to clipboard
172E42
Hedgehog mode
Inverse system
enabled
Distances only mode
disabled
Supply voltage, V
3.96
High voltage, V
n/a
Height, m (-320.000..320.000)
0.000
Time from reset, h:m:s
00:00:13 R
Measured temperature, °C
39
RSSI, dBm
-46
Radio frequency band
Carrier frequency, MHz
919.000
Device address (0..99)
22
Channel
0
Minimum threshold (-10..-2000)
IMU
(+) expand
Parameters of radio
(+) expand
Ultrasound
(+) expand
Interfaces
(+) expand
Misc. settings
(+) expand
Hedgehogs pairing
(+) expand
Processor's crystal's temperature
Strength of the radio signal from this beacon to the modem, i.e. how the modem "hears" the beacon over radio. Keep below -25dBm and above -80..90dBm to avoid losses of packets. Lower end depends on radio profile and interference
Select radio frequency band according to your HW: 433MHz or 915MHz
Real carrier frequency
Selected device's address
Selected radio channel
TBD

IMU



Parameters of radio




Parameters of radio
(-) collapse
Base frequency, MHz
919.000
Radio profile
38 Kbps
Device address (0..99)
77
Channel
1
Modulation
GFSK
Power of TX
9 dBm
Channel spacing, KHz (25.391..405.457)
49.190
Intermediate frequency (ID), KHz (0..787)
152
Offset frequency, KHz (-203.13..201.54)
76.16
Deviation frequency, KHz (1.587..380.859)
20.628
Channel bandwidth, KHz (58.036..812.500)
101.553
CCA mode
always
DC blocking filter
enabled
Manchester
disabled
Whitening
enabled
FEC
enabled
Radio profile settings. No need to change manually. Only for advanced users
Radio profile settings. No need to change manually. Only for advanced users
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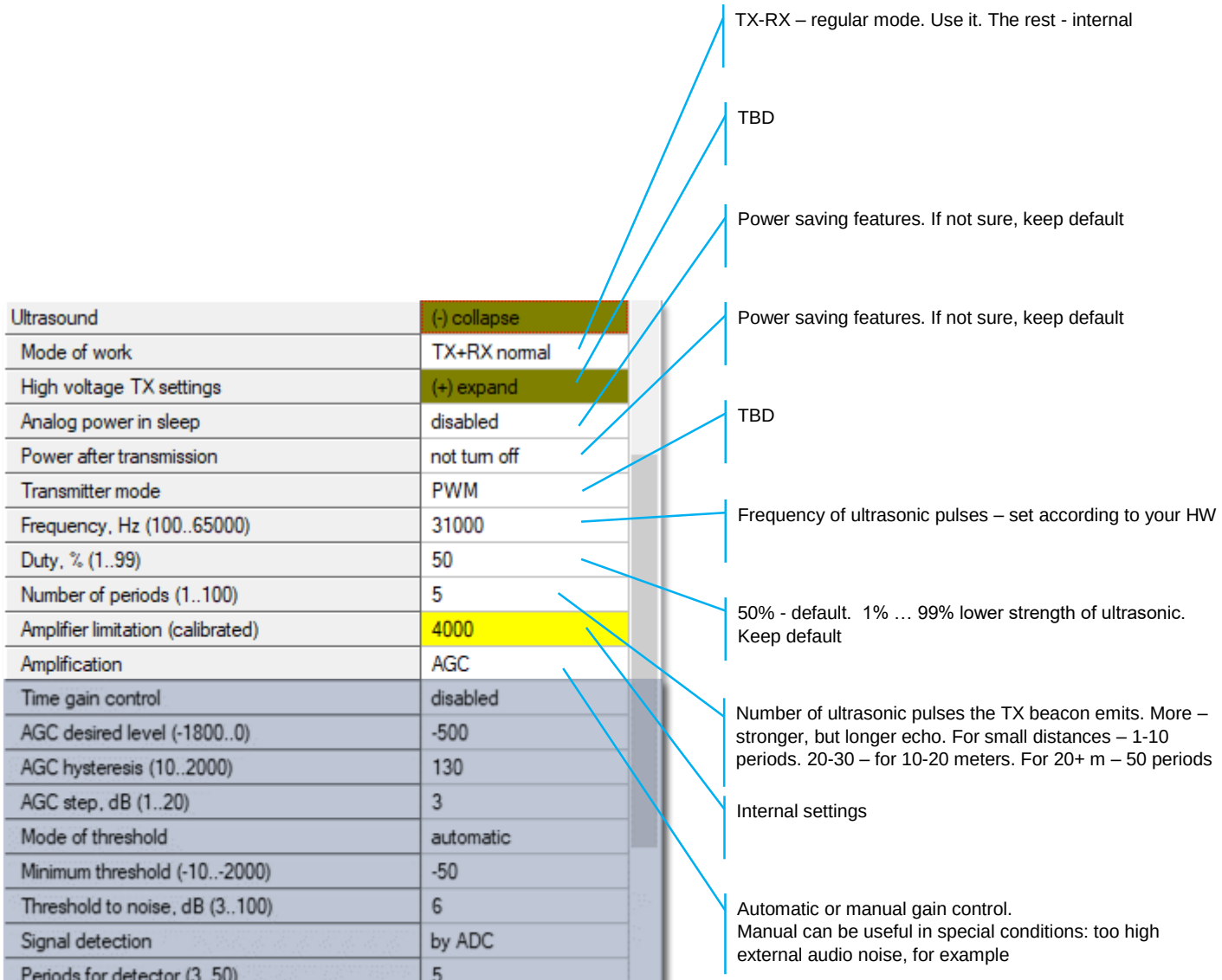
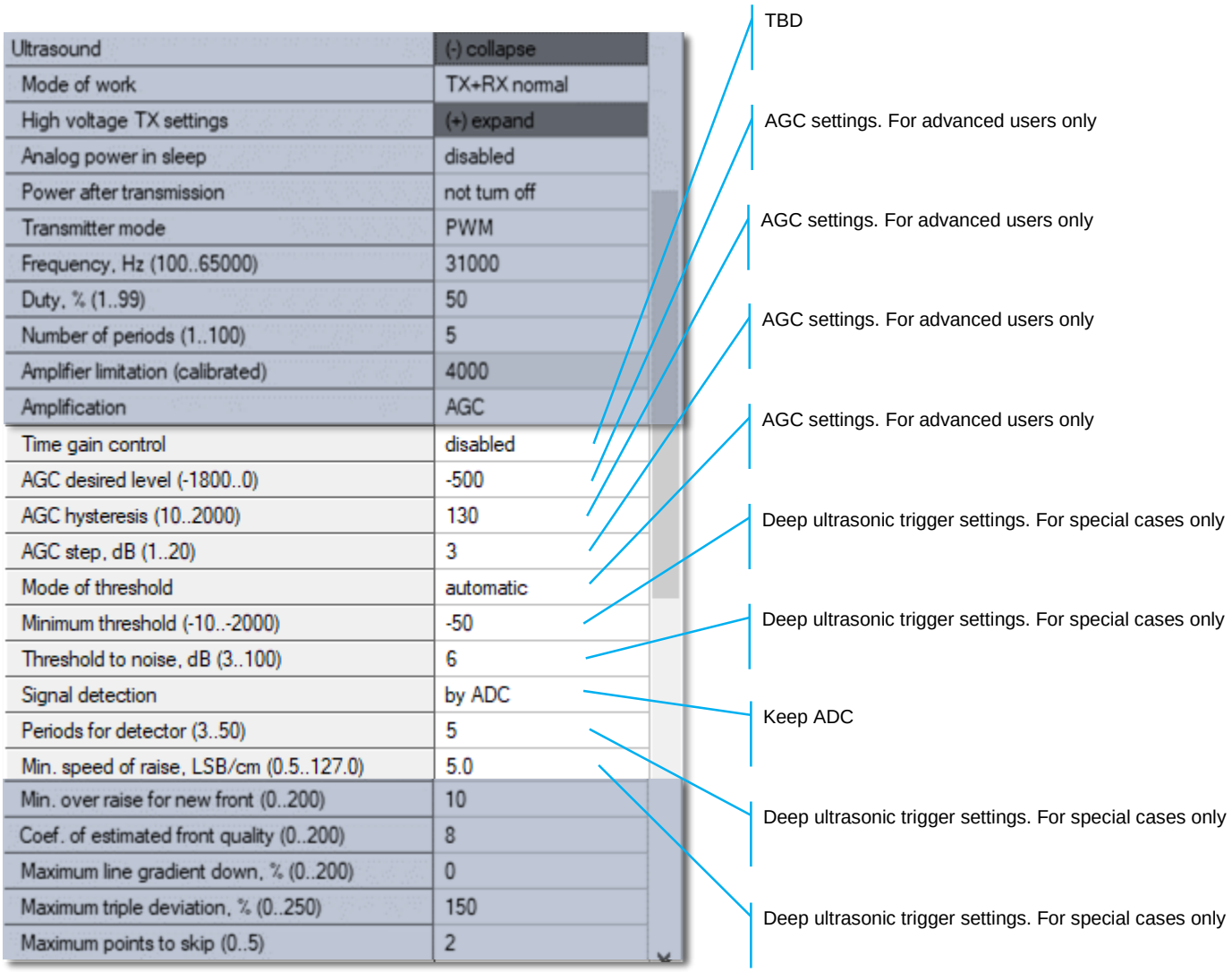
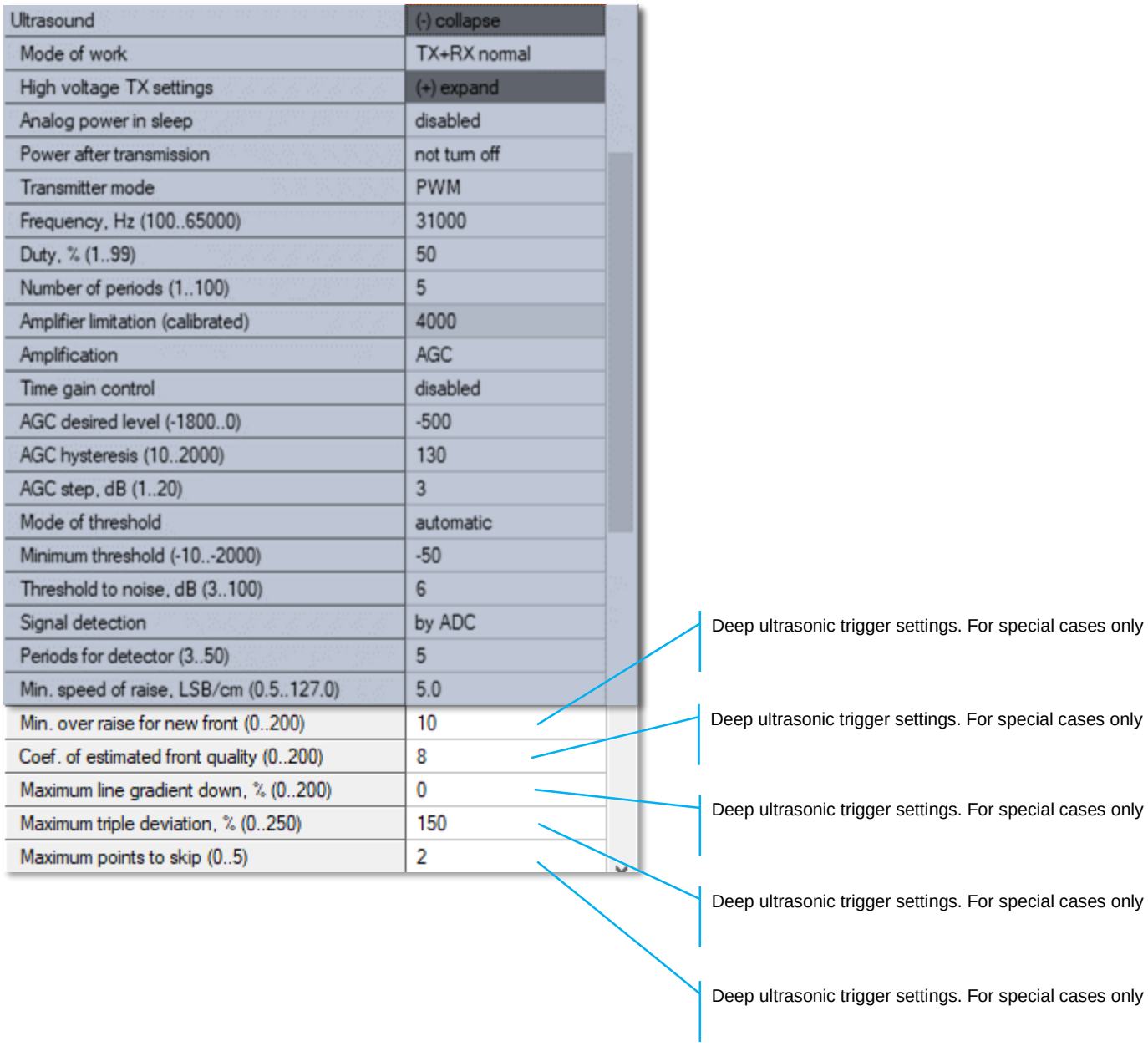
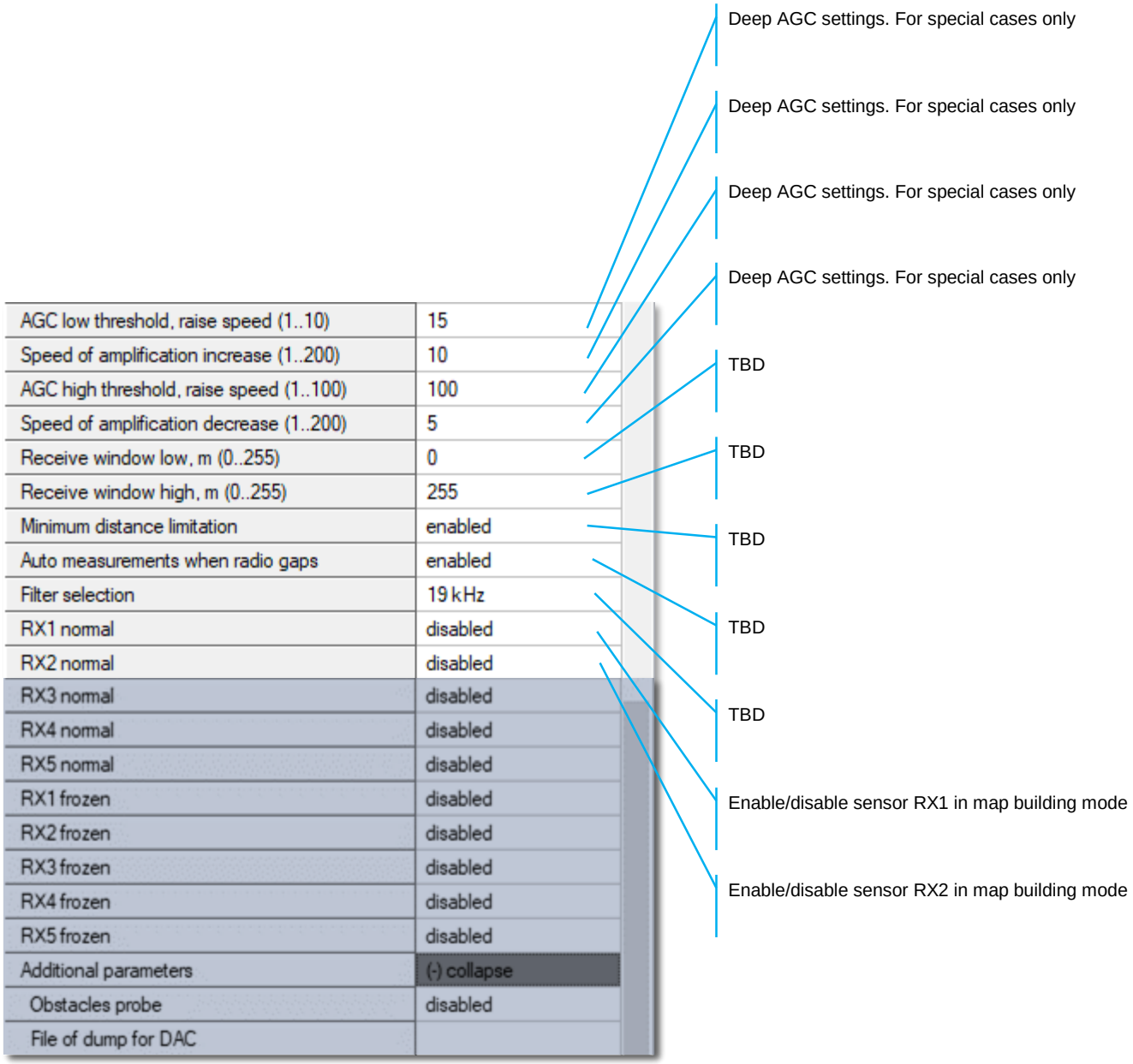
Radio profile settings. No need to change manually. Only for advanced users

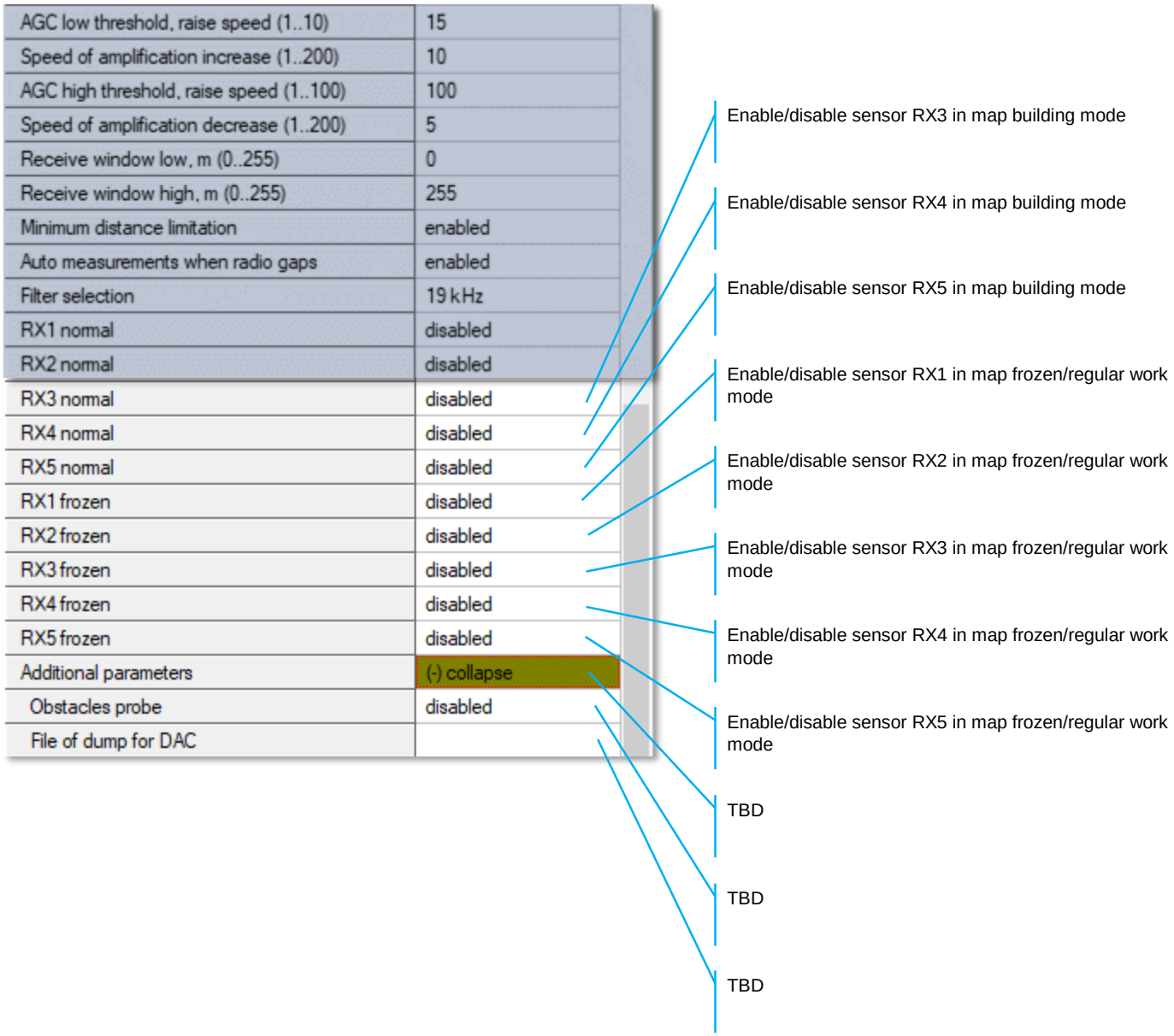
Ultrasound



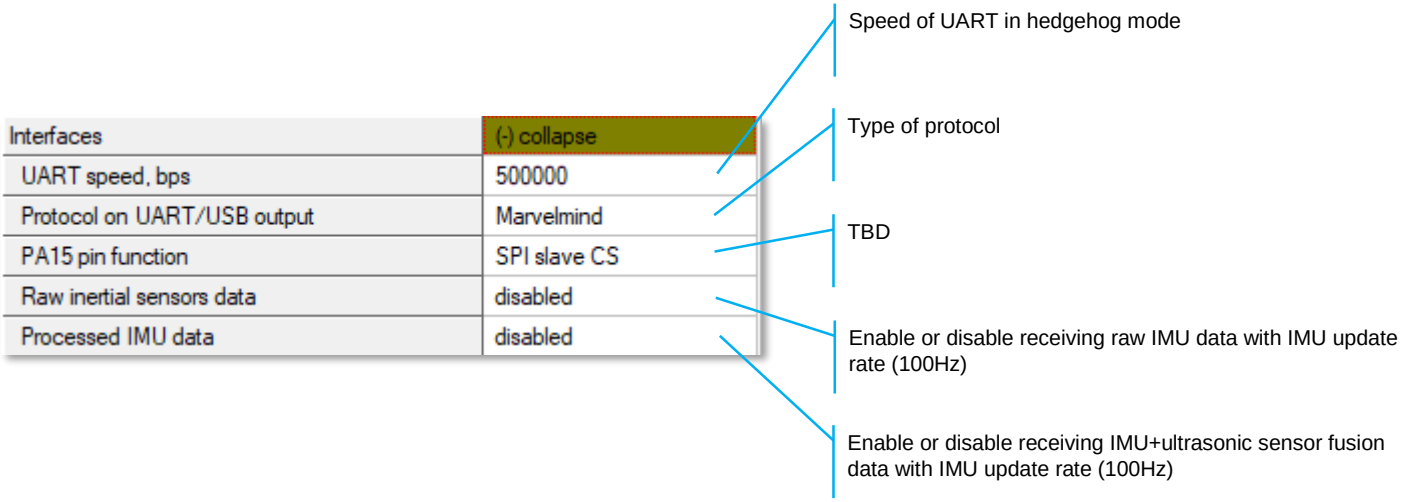

Ultrasound
(-) collapse
Mode of work
TX+RX normal
High voltage TX settings
(+) expand
Analog power in sleep
disabled
Power after transmission
not turn off
Transmitter mode
PWM
Frequency, Hz (100..65000)
31000
Duty, % (1..99)
50
Number of periods (1..100)
5
Amplifier limitation (calibrated)
4000
Amplification
AGC
Time gain control
disabled
AGC desired level (-1800..0)
-500
AGC hysteresis (10..2000)
130
AGC step, dB (1..20)
3
Mode of threshold
automatic
Minimum threshold (-10..-2000)
-50
Threshold to noise, dB (3..100)
6
Signal detection
by ADC
Periods for detector (3..50)
5
Min. speed of raise, LSB/cm (0.5..127.0)
5.0
Min. over raise for new front (0..200)
10
Coef. of estimated front quality (0..200)
8
Maximum line gradient down, % (0..200)
0
Maximum triple deviation, % (0..250)
150
Maximum points to skip (0..5)
2
TBD
AGC settings. For advanced users only
AGC settings. For advanced users only
AGC settings. For advanced users only
AGC settings. For advanced users only
Deep ultrasonic trigger settings. For special cases only
Deep ultrasonic trigger settings. For special cases only
Keep ADC
Deep ultrasonic trigger settings. For special cases only
Deep ultrasonic trigger settings. For special cases only


Ultrasound
(-) collapse
Mode of work
TX+RX normal
High voltage TX settings
(+) expand
Analog power in sleep
disabled
Power after transmission
not turn off
Transmitter mode
PWM
Frequency, Hz (100..65000)
31000
Duty, % (1..99)
50
Number of periods (1..100)
5
Amplifier limitation (calibrated)
4000
Amplification
AGC
Time gain control
disabled
AGC desired level (-1800..0)
-500
AGC hysteresis (10..2000)
130
AGC step, dB (1..20)
3
Mode of threshold
automatic
Minimum threshold (-10..-2000)
-50
Threshold to noise, dB (3..100)
6
Signal detection
by ADC
Periods for detector (3..50)
5
Min. speed of raise, LSB/cm (0.5..127.0)
5.0
Min. over raise for new front (0..200)
10
Coef. of estimated front quality (0..200)
8
Maximum line gradient down, % (0..200)
0
Maximum triple deviation, % (0..250)
150
Maximum points to skip (0..5)
2
Deep ultrasonic trigger settings. For special cases only
Deep ultrasonic trigger settings. For special cases only
Deep ultrasonic trigger settings. For special cases only
Deep ultrasonic trigger settings. For special cases only
Deep ultrasonic trigger settings. For special cases only

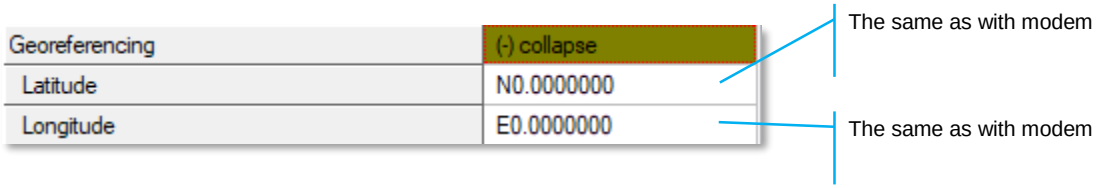

AGC low threshold, raise speed (1..10) 15
Speed of amplification increase (1..200) 10
AGC high threshold, raise speed (1..100) 100
Speed of amplification decrease (1..200) 5
Receive window low, m (0..255) 0
Receive window high, m (0..255) 255
Minimum distance limitation enabled
Auto measurements when radio gaps enabled
Filter selection 19 kHz
RX1 normal disabled
RX2 normal disabled
RX3 normal disabled
RX4 normal disabled
RX5 normal disabled
RX1 frozen disabled
RX2 frozen disabled
RX3 frozen disabled
RX4 frozen disabled
RX5 frozen disabled
Additional parameters (-) collapse
Obstacles probe disabled
File of dump for DAC
Deep AGC settings. For special cases only
Deep AGC settings. For special cases only
Deep AGC settings. For special cases only
Deep AGC settings. For special cases only
TBD
TBD
TBD
TBD
TBD
Enable/disable sensor RX1 in map building mode
Enable/disable sensor RX2 in map building mode


AGC low threshold, raise speed (1..10) 15
Speed of amplification increase (1..200) 10
AGC high threshold, raise speed (1..100) 100
Speed of amplification decrease (1..200) 5
Receive window low, m (0..255) 0
Receive window high, m (0..255) 255
Minimum distance limitation enabled
Auto measurements when radio gaps enabled
Filter selection 19 kHz
RX1 normal disabled
RX2 normal disabled
RX3 normal disabled
RX4 normal disabled
RX5 normal disabled
RX1 frozen disabled
RX2 frozen disabled
RX3 frozen disabled
RX4 frozen disabled
RX5 frozen disabled
Additional parameters (-) collapse
Obstacles probe disabled
File of dump for DAC
Enable/disable sensor RX3 in map building mode
Enable/disable sensor RX4 in map building mode
Enable/disable sensor RX5 in map building mode
Enable/disable sensor RX1 in map frozen/regular work mode
Enable/disable sensor RX2 in map frozen/regular work mode
Enable/disable sensor RX3 in map frozen/regular work mode
Enable/disable sensor RX4 in map frozen/regular work mode
Enable/disable sensor RX5 in map frozen/regular work mode
TBD
TBD
TBD

Interfaces

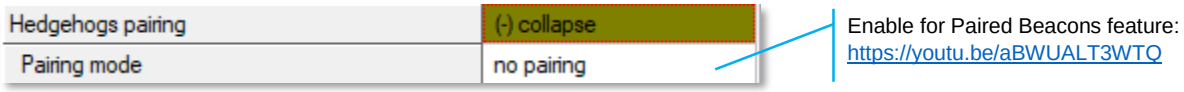

Interfaces
(-) collapse
UART speed, bps
500000
Protocol on UART/USB output
Marvelmind
PA15 pin function
SPI slave CS
Raw inertial sensors data
disabled
Processed IMU data
disabled
Speed of UART in hedgehog mode
Type of protocol
TBD
Enable or disable receiving raw IMU data with IMU update rate (100Hz)
Enable or disable receiving IMU+ultrasonic sensor fusion data with IMU update rate (100Hz)

Georeferencing



Misc. settings

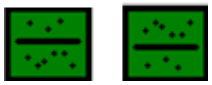
Hedgehogs pairing



Enable for Paired Beacons feature:
https://youtu.be/aBWUALT3WTQ

6.8 CEILLING and MIRRORING buttons on the Dashboard

- The **MIRRORING** button allows the map to be display as a mirror reflection



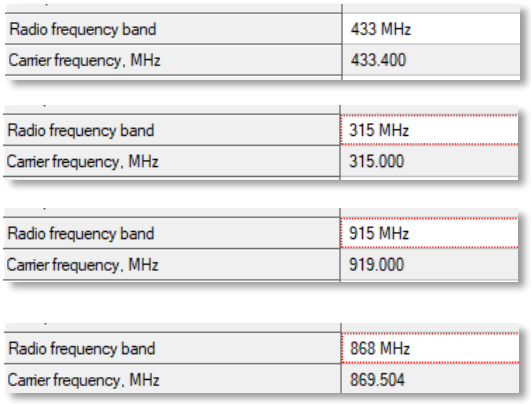
- The **CEILING** button shows where the mobile beacon is located with respect to the stationary beacons

- When the arrow points up, it means that the mobile beacon is below the stationary beacons

- When the arrow points down, it means that the mobile beacon is **above the stationary beacons**

6.9 Radio frequency band and Carrier frequency

- For beacons and modems 433 MHz allowable Radio bands 315 and 433,
- For beacons and modems 915 MHz allowable Radio bands 868 and 915, but when using antennas at 433 MHz it is possible to use both 315 and 433 MHz



Radio frequency band	433 MHz
Carrier frequency, MHz	433.400

Radio frequency band	315 MHz
Carrier frequency, MHz	315.000

Radio frequency band	915 MHz
Carrier frequency, MHz	919.000

Radio frequency band	868 MHz
Carrier frequency, MHz	869.504

6.10 Different hedgehog colors in the Dashboard

- **Blue** - normal mode and confident tracking
- **Orange** - system provides the best location data possible, but confidence is lower, than blue
- **Colorless / transparent** - usually, means lost radio packets or no ultrasound coverage

7. SW feature descriptions

7.1 Major update 08/27/2018 features

That big update contains some huge features. **That update compatible with HW v4.9 only**

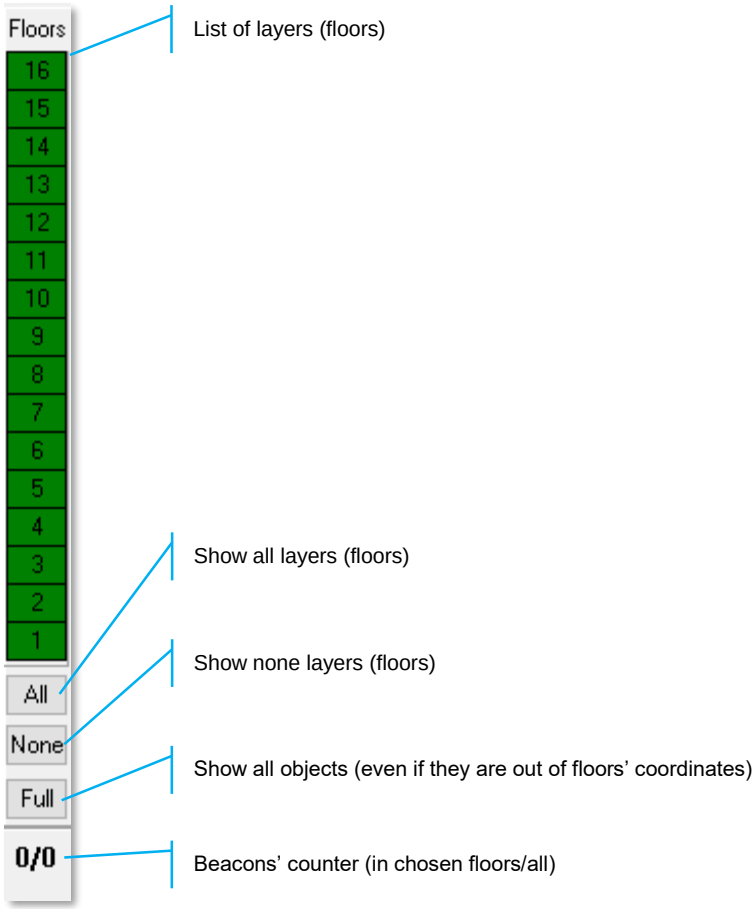
Main features:

- Floors
- Axis extension (3D map view with 90° step, submaps rotations)
- Vertical submaps

Floors feature

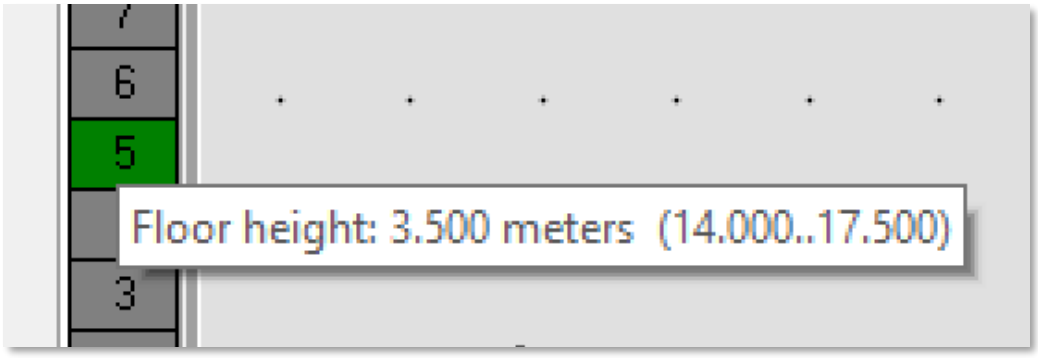
The general view

Floor feature allows to build complicated multi-level maps. Every submap correspond some height, height corresponds to floors.

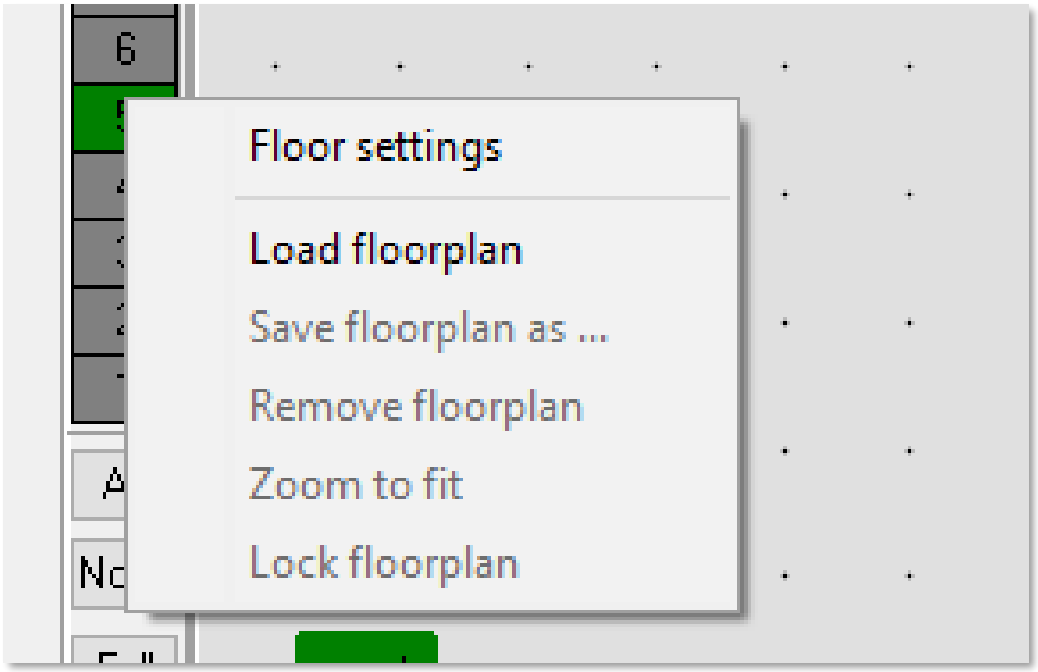


Floor's settings

- Every floor has its own adjustable height and its own floor plan



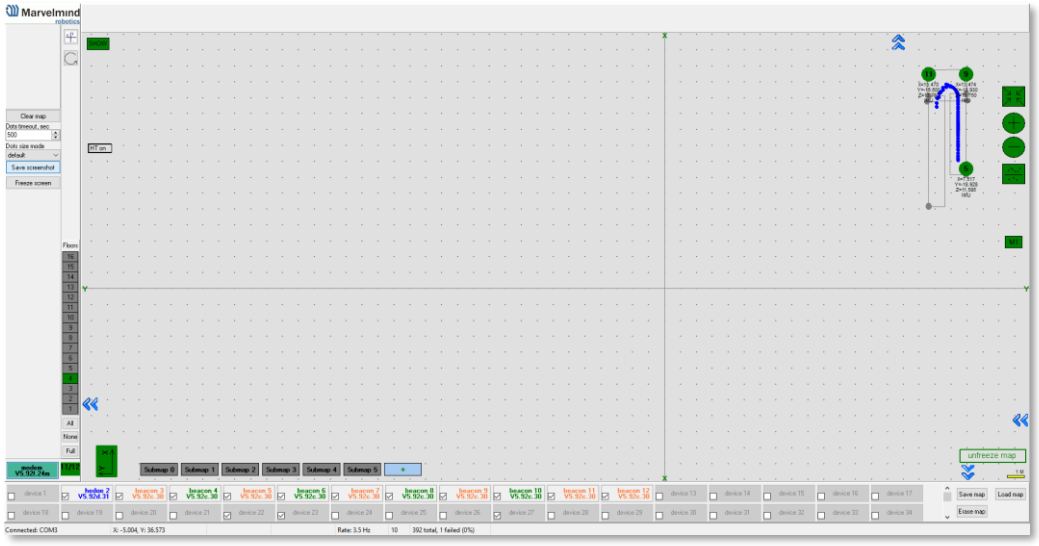
- Use right mouse button on the floor area to see an additional menu. There you can change floor's height. You can also insert your floorplan for that floor (.png, .jpeg, .bmp, .tiff)



Floor 4 and 5 are enabled:

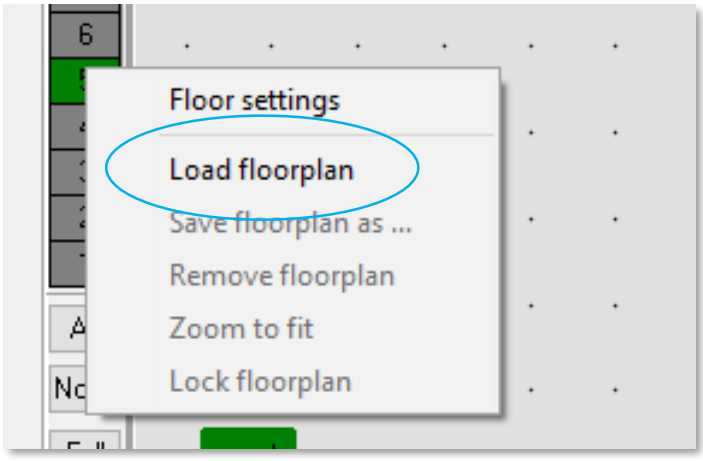
Floor 5 is enabled:

Floor 4 is enabled:



Loading the floorplan

- **RMB click on the floor -> Load floorplan -> Choose file** (.png, .jpeg, .bmp, .tiff).
- When the picture is loaded, you can drag the beacons to the points where they are actually located. After dragging two beacons, the picture with beacons will be combined in scale

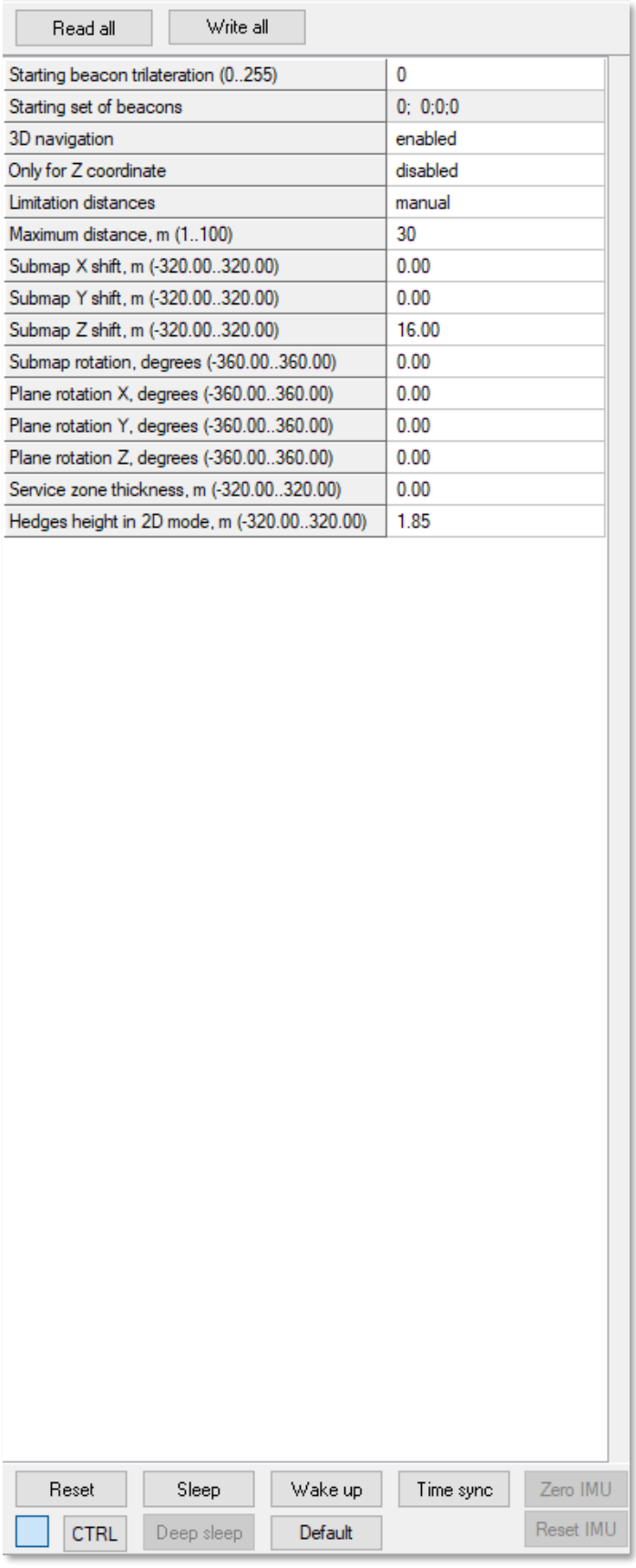


Submap's settings

Every submap got its own settings. To correspond your submap to a certain floor, you need to adjust the height:

- To open that settings, use **left mouse button** on the **submap icon** - 

- Change **Submap Z shift** value

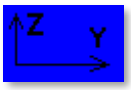


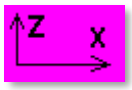
Axis extension

General view

Axis extension allows user to rotate the map. There are the 90° gap between views.
It helps in case of multifloor tracking, when it is important to have a side view.

There are 3 directions of view:



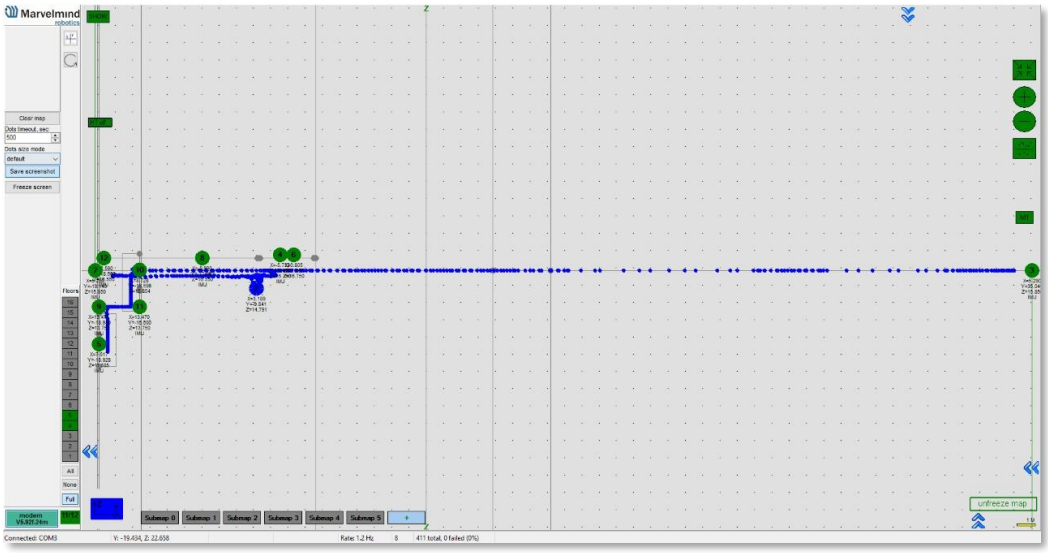


- To change view, click on the icon

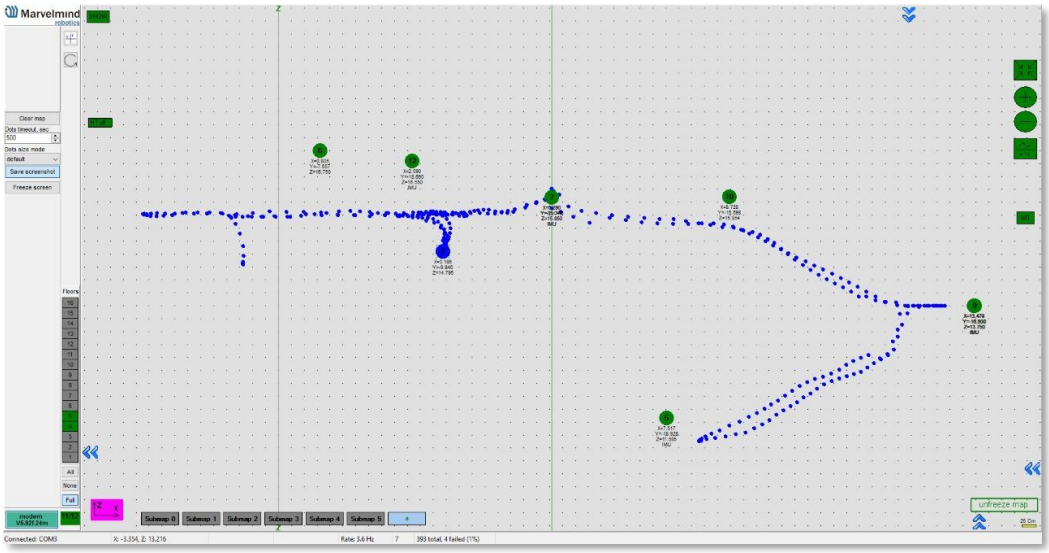
Example of views:

Y, X

X, Y



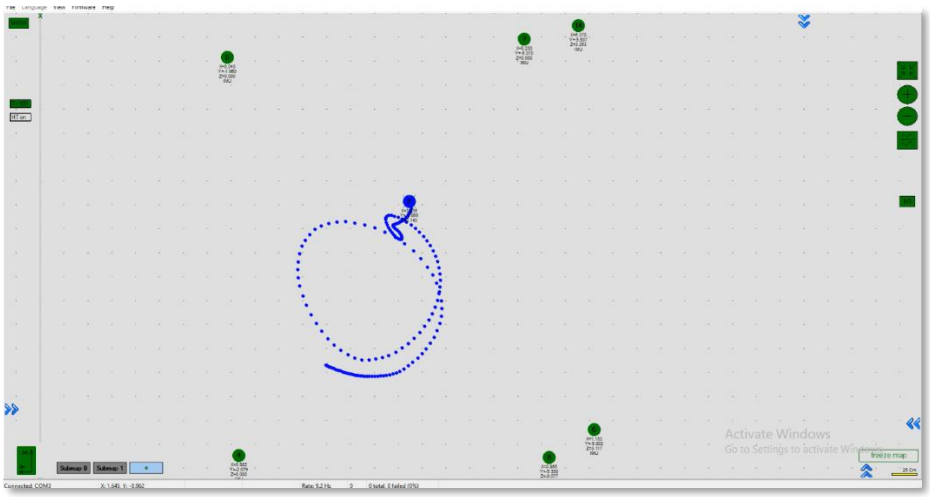
Z, X

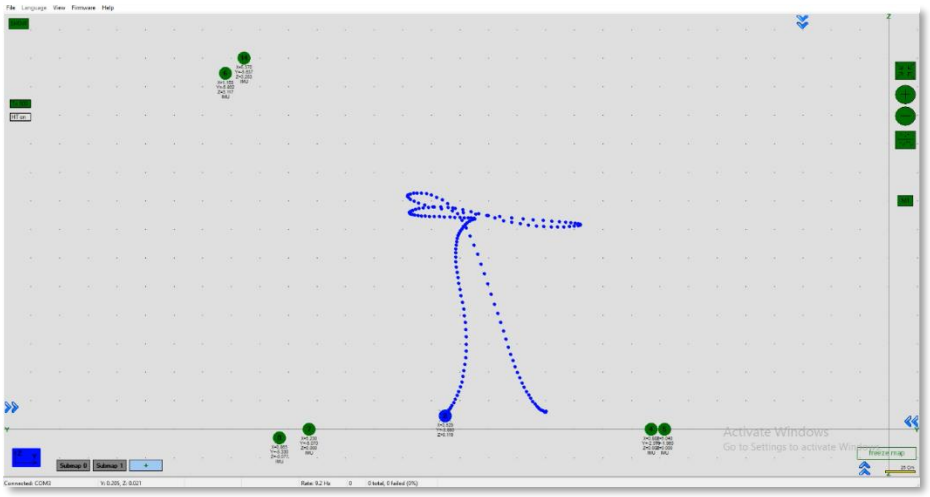

Marvelmind
robotics
Clear map
Data timeout, sec
500
Dots size mode
default
Save screenshot
Freeze screen
Floors
All
None
Full
modem
Submap 0
Submap 1
Submap 2
Submap 3
Submap 4
Submap 5
unfreeze map

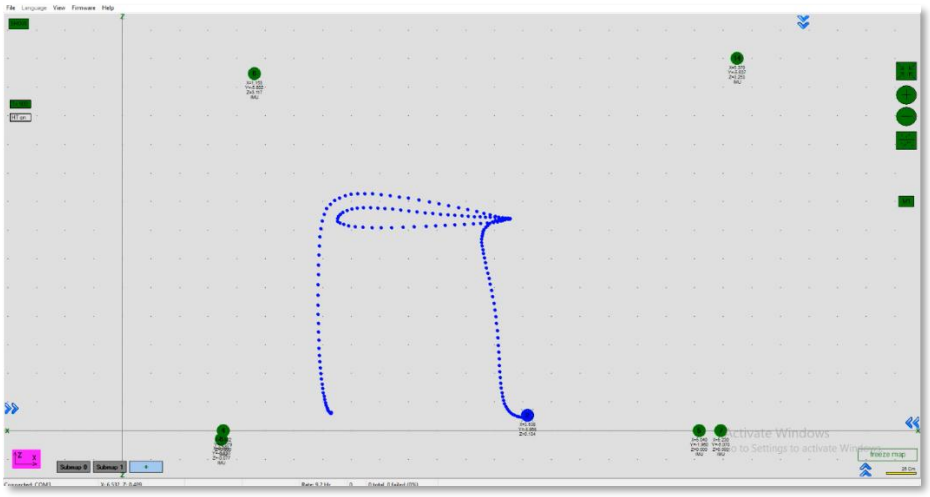
Vertical submaps

Vertical submap is a new feature for drone flights or some other specific cases. It gives user an opportunity to get a solid Z data for a vertical movement

Example: The drone flight







How to build vertical submap for stable Z:

1) For that configuration you need 6 stationary beacons

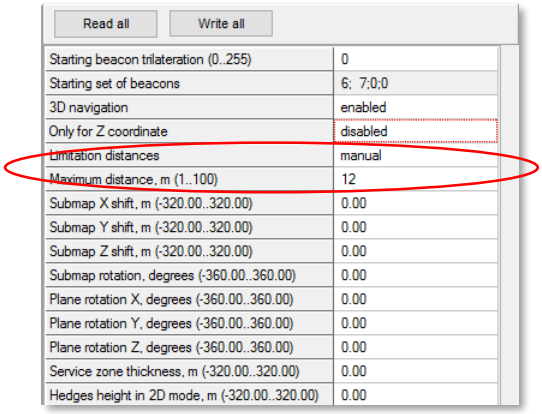
2) Place 4 bacons on the ground, facing each other. (make a square, where the edge points are beacons, looking in the center)

3) Place two beacons high on wall

4) Turn on RX4 only for beacons on the ground and RX4 and RX2 for beacons on the wall

5) Build the first submap (horizontal) consisting of all ground beacons

6) Change **Limitation distance** to **manual** and input the value in the submap's settings



7) Freeze and lock it

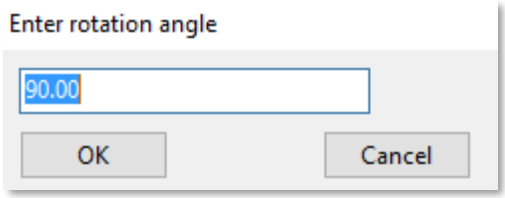
8) Build the second submap (vertical) horizontally consisting of two wall beacons and two ground beacons (neighboring with wall beacons)

9) Now, freeze it

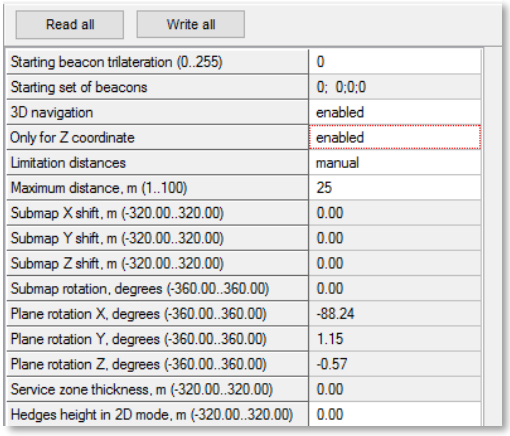
10) Press axis rotation button 

11) Click on the axis you want to rotate your submap along (when you point the cursor on the axis, it became visible and pink-colored)

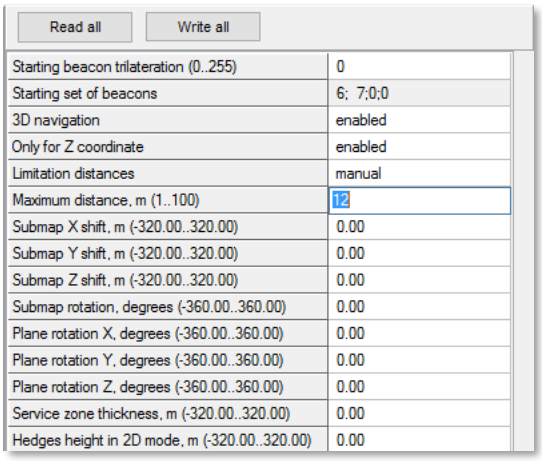
12) Enter the corner value (90° usually)



13) Choose submap 2 and enable “Only for Z coordinates” mode



14) Change **Limitation distance** value



15) Change views and check the map

16) Wake up mobile beacon

17) Track

7.2 Submaps feature

Submaps is a very powerful feature that allows building large maps (full business center, factory, warehouse with total area of 10,000...300,000 or more) based on smaller submaps (30...1000m2)

A submap is a part of the map. It includes a subset of used beacons covering part of the navigation area. Current version of Marvelmind system can include up to 10 submap. Please also check our help video.

Follow these steps:

Step 1. Choose the beacons which will be added to certain submap0…submapN

Step 2. Connect the modem and put all the beacons into sleeping mode

Step 3. Click “erase map” button for removing some current settings of beacons and submaps

Step 4. Wake up all the beacons which should be served by submap0

Step 5. Wait a little for map will automatically build. If needed use mirroring function

Step 6. Freeze the submap

Step 7. Add the new submap by clicking “+” button. New submap is automatically chosen as active

Step 8. Wake up the beacons which should be served by submap1. By default, all the beacons are served by the last unfrozen submap

Step 9. If the new submap should include beacons which are at the moment served by previous submaps (intersected submaps) click on each beacon, then right-mouse-click=>Add to current submap

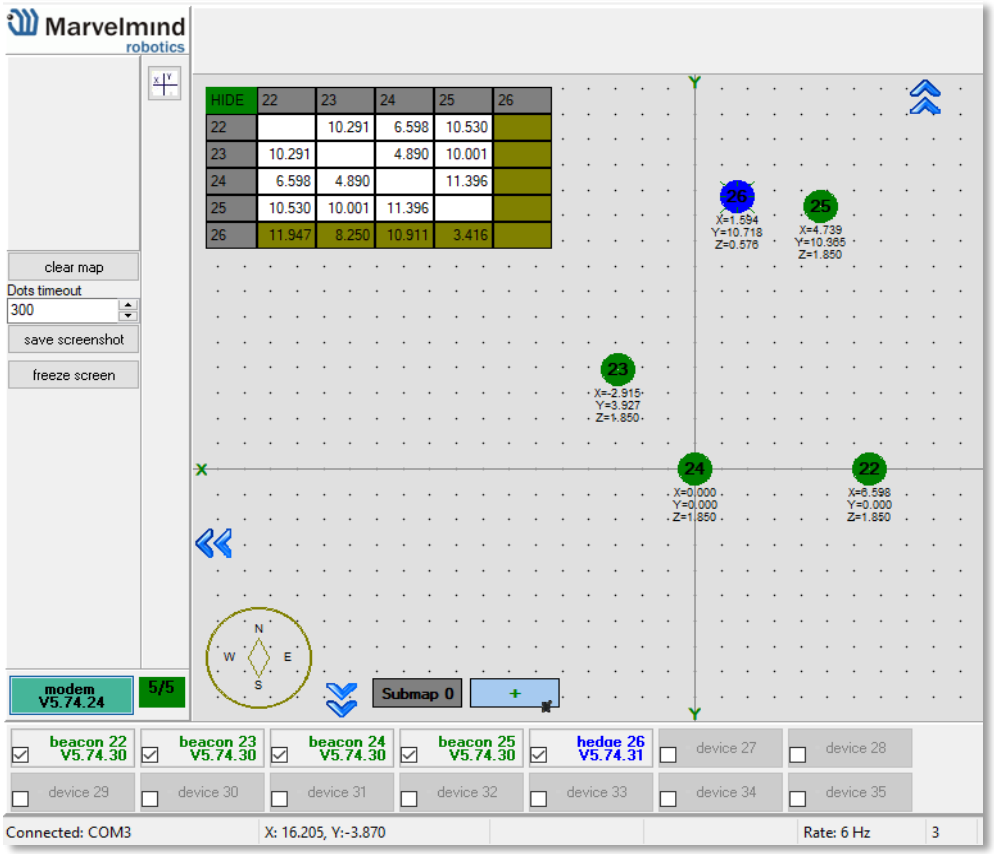
Step 10. If the new submap has 1 or 2 common beacons with previous submaps, it will settle as a part of the already built map. Two common beacons give a tight binding. If there is only one common beacon it’s possible to drag and drop the submap. If submaps do not have common beacons it is needed to drag and drop the selected submap using the mouse and holding down the CTRL button. Rotation of submap can be executed by using the mouse wheel

Step 11. Align submaps using M1/M2 parameter

Step 12. Set Service Zones for each submap

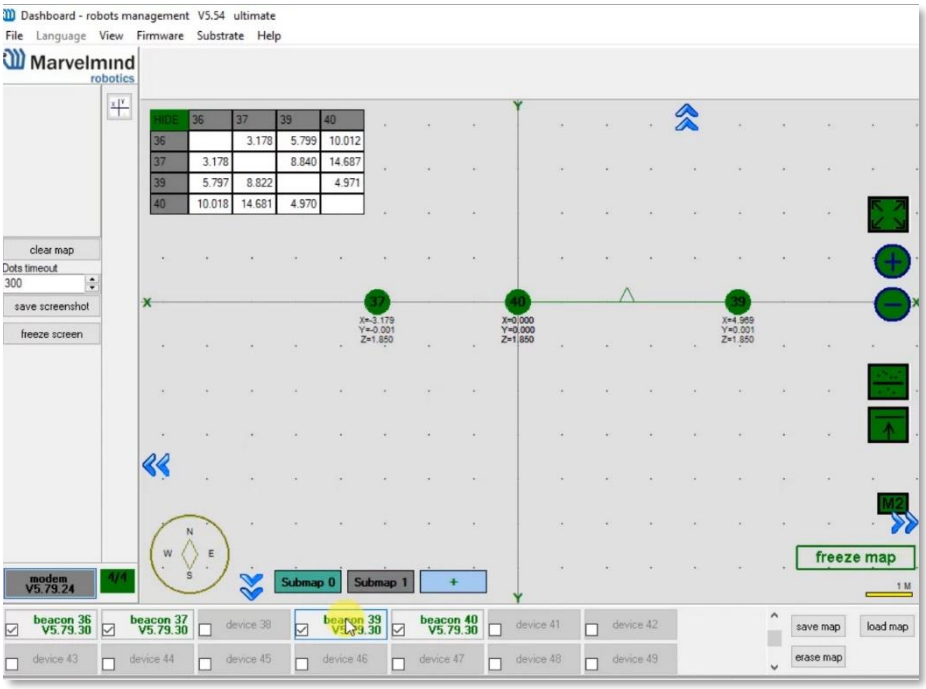
Starting submaps

- Hedgehogs do not belong to any submap and can move between sub-map areas. Hedgehogs can be served not by only one submap at the same time. By default, the map consists of single sub-map, Submap0
- After adding new beacons to the system (waking them up), they appear in the first not frozen submap, or in the Submap0 if all the beacons are frozen
- Pressing the “+” button, add new empty submap to the system



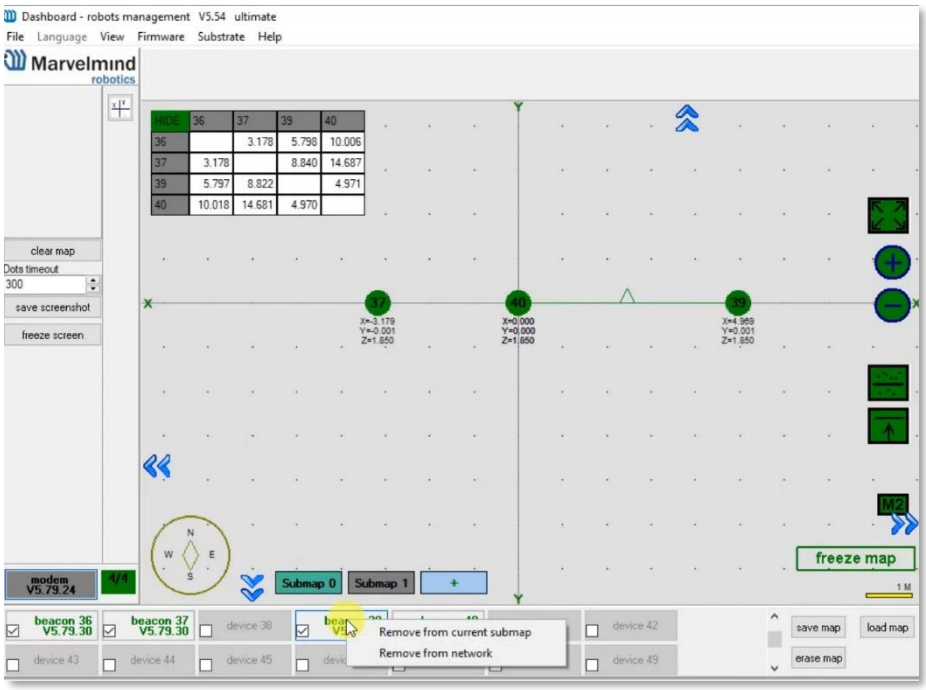
- Press the button with the submap number (Submap0, Submap1 etc.) - select the corresponding submap
- In this state, if the modem button is pushed, the list of parameters on the right side represents some of the parameters of the selected submap, for example, “Starting beacon trilateration,” “Starting set of beacons,” etc.

- The system after adding beacons to the Submap0, adding new submap and the selection of Submap0



- Now we have 4 beacons, all in Submap0 (it can be seen near the table of distances)

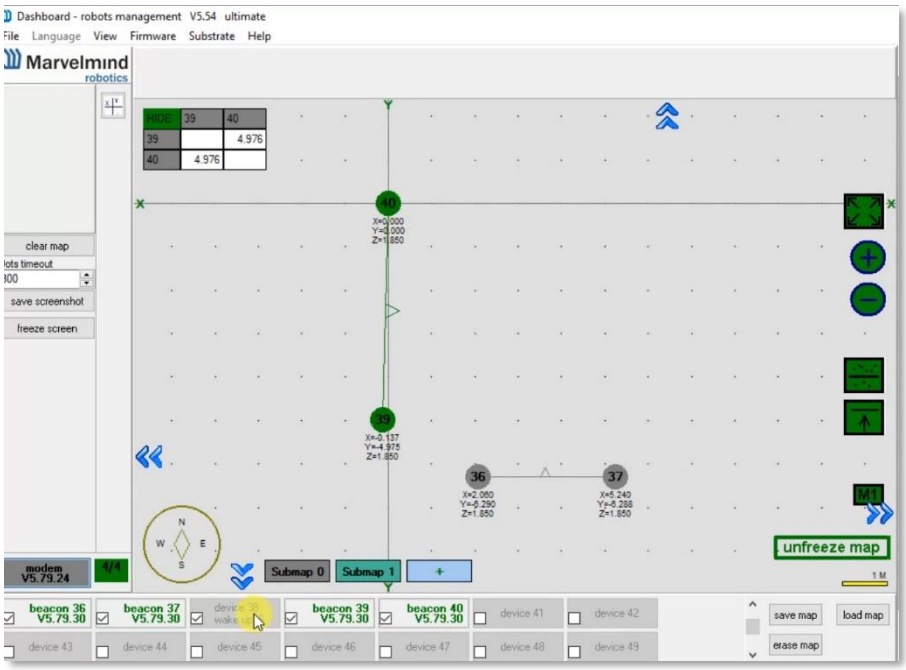
- When the submap selected, the context menu of beacons buttons (available by right clicking the mouse) have the functions of adding and removing the beacons from the submap. In the picture above, we are removing beacon 3 from Submap0." Then we switch to Submap1 and add



this beacon to the submap

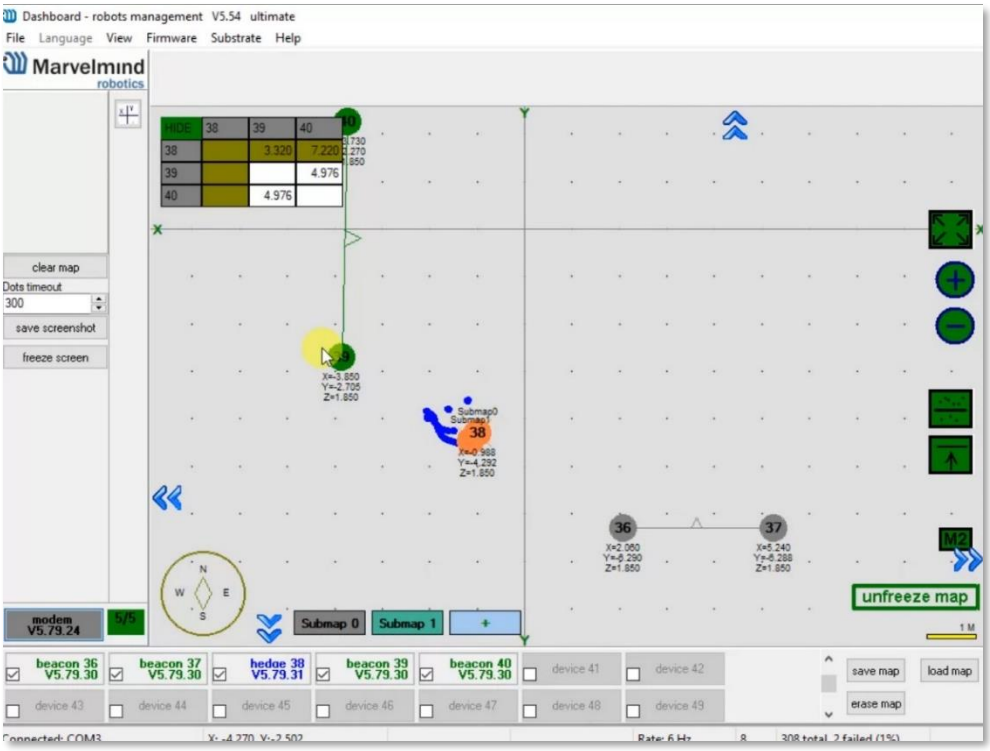
- When the submap selected, the beacons that do not belong to the submap are colored **gray**. In the same way, continue with removing beacon 10 from Submap0 and adding it to Submap1

- Now there are two beacons in Submap1, so this submap is built. “Submap 0” is built as well. Now we can freeze both submaps
- If pressing the “freeze map” button when the submap is selected, only the selected submap will be frozen. If pressing the “freeze map” button when the modem button is selected, all submaps will be frozen
- Now we have two good submaps, but they are not correctly located relative to each other. On the right side exist the parameters of shift and rotation for the selected submap; they can be filled in by hands. But a more user friendly way is to drag and drop the selected submap using the mouse and holding down the CTRL button.
- Rotation of submap can be executed by using the mouse wheel. The mirroring button also can be used; it affects only submaps that are selected



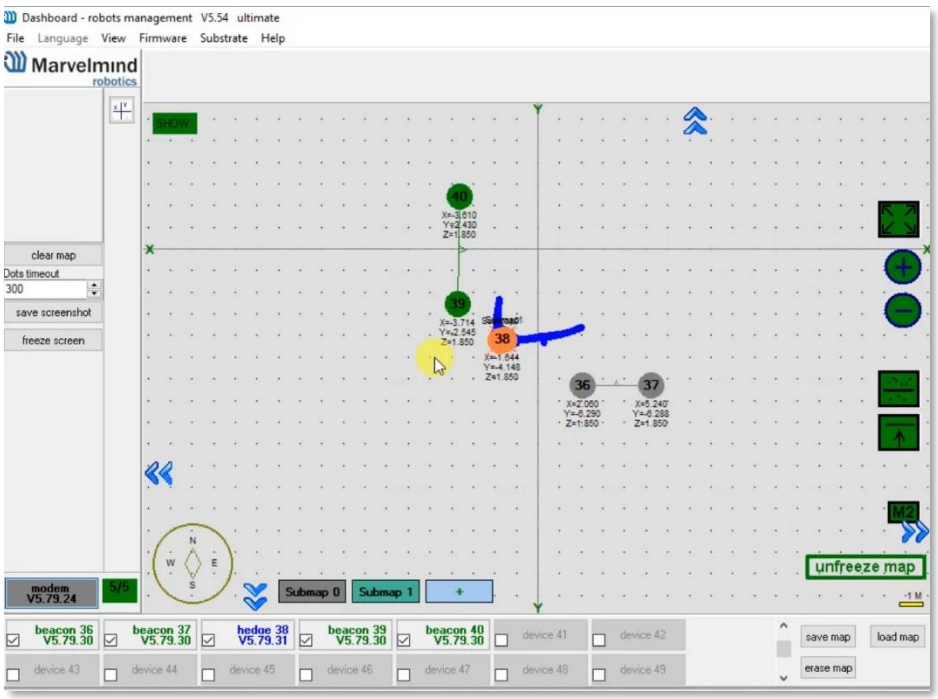
- After some movement, rotation, and mirroring of submaps, we can locate the submaps close to their real relative location
- Now the system is ready to use; we can wake up and track the mobile hedgehog
- In some cases the hedgehog can be lost between the submaps if this area is not covered by any of the submaps.

- Submaps can be removed from system using the context menu of the submap selection button (available with a right mouse click)M1/M2 parameter used for precise superposing submaps which do not have common beacons. So submaps cannot be aligned automatically



To align submaps:

1. Build the system like in previous instruction (1-11)
2. Put M2 in mode on by clicking the icon. Place the hedgehog near the boundary between two submaps. You will see 2 orange hedgehogs blinking, this is how the hedge is seen in two submaps
3. To align submaps correctly (CTRL + scroll/drag) against each other, until the orange mobile beacons are fully overlapped
4. Replace hedgehog to 1 or 2 points and repeat replacing submap for better superposing

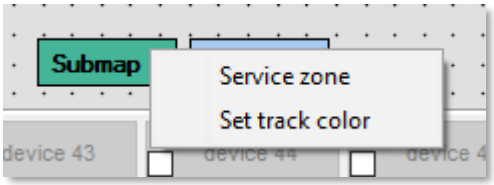


Next step is to set service zones

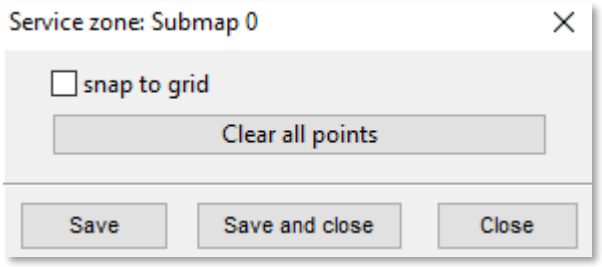
Service zones are zones where the tracking is possible. If mobile beacon is out of the service zone it would not be tracking. If you built complicated map, you have to make service zones correctly. Service zones must be crossing in order to provide correct and glide tracking.

How to create a service zone:

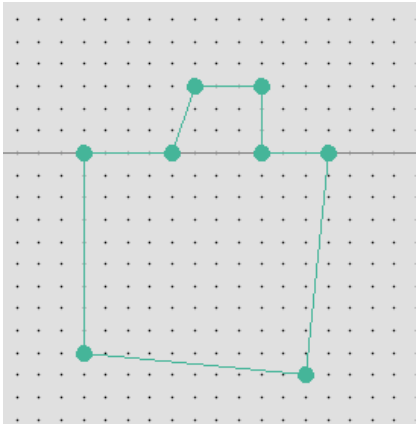
- **RMB on the submap icon -> Service zone**



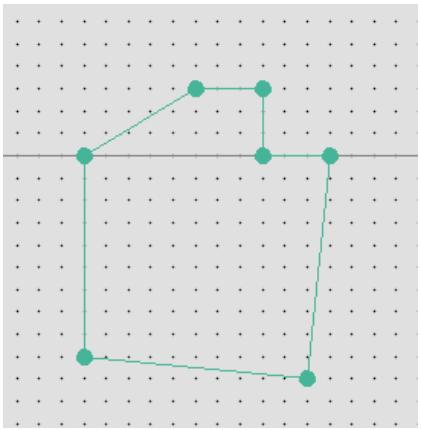
- The service zone menu will open



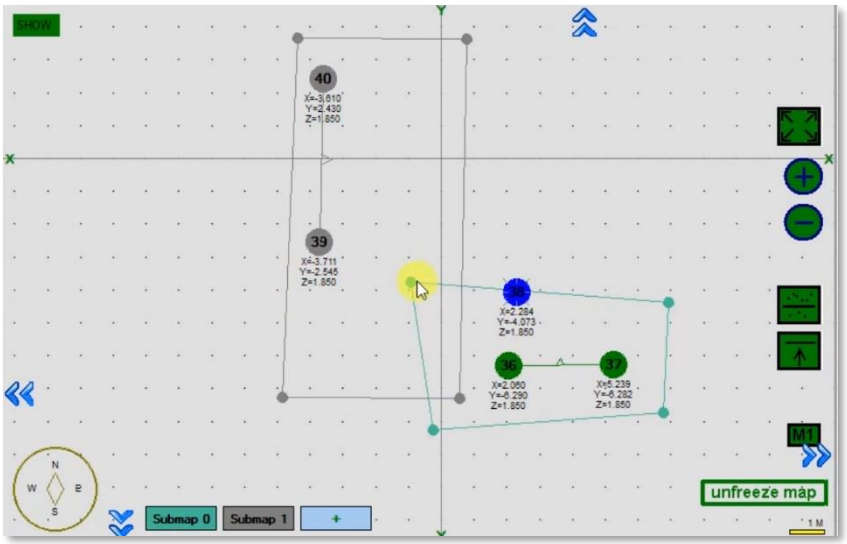
- Use **SHIFT + LMB** on the map to create point



- Use **SHIFT + LMB** on the point to delete it



- Put points around submap, move them to provide service area for current submap. Service areas will cross each other. If hedgehogs get lost between two submaps expand the service area.

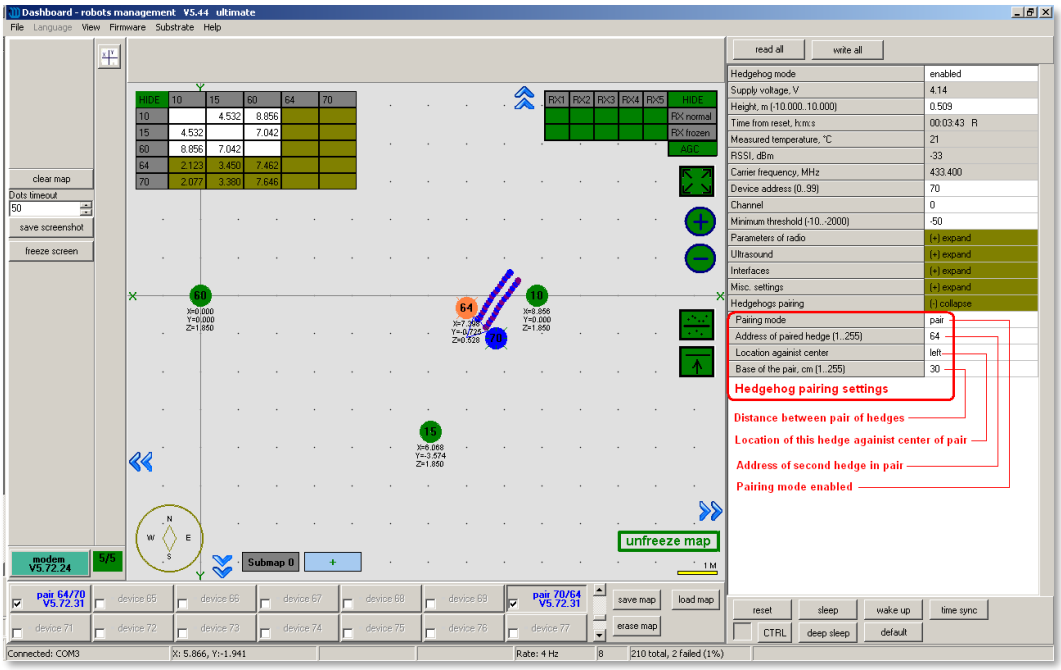

SHOW
40
X=-3.610
Y=2.430
Z=1.850
39
X=-3.711
Y=-2.545
Z=1.850
X=2.284
Y=-4.073
Z=1.850
X=2.060
Y=-6.290
Z=1.850
X=5.239
Y=-6.282
Z=1.850
M1
unfreeze map
Submap 0
Submap 1
+
1 M

7.3 Paired beacons

- Two hedgehogs can be paired and work together as a single beacon without update rate reduction.
- Moreover, each beacon streams out in this mode not only its own location, but direction where the pair is facing. This feature hugely simplifies autonomous driving and flight. Here is updated protocol with the changes
- Please, also check our help video.

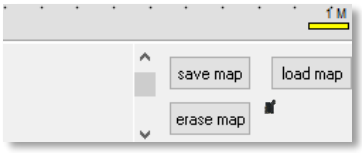
Follow these steps:

1. Wake up stationary beacons and freeze the map
2. Wake up two hedgehogs which were pre-installed on robot/copter/drone
3. Choose one beacon and go to “Pairing mode” parameter and activate
4. Write the “Address of paired beacon”, means number of the beacon, current selected hedgehog is paired with
5. Now choose location against center in parameters relatively the second beacon
6. Go to “Base of the pair” parameter and write actual distance between paired hedgehogs. Do the same for 2nd hedgehog.



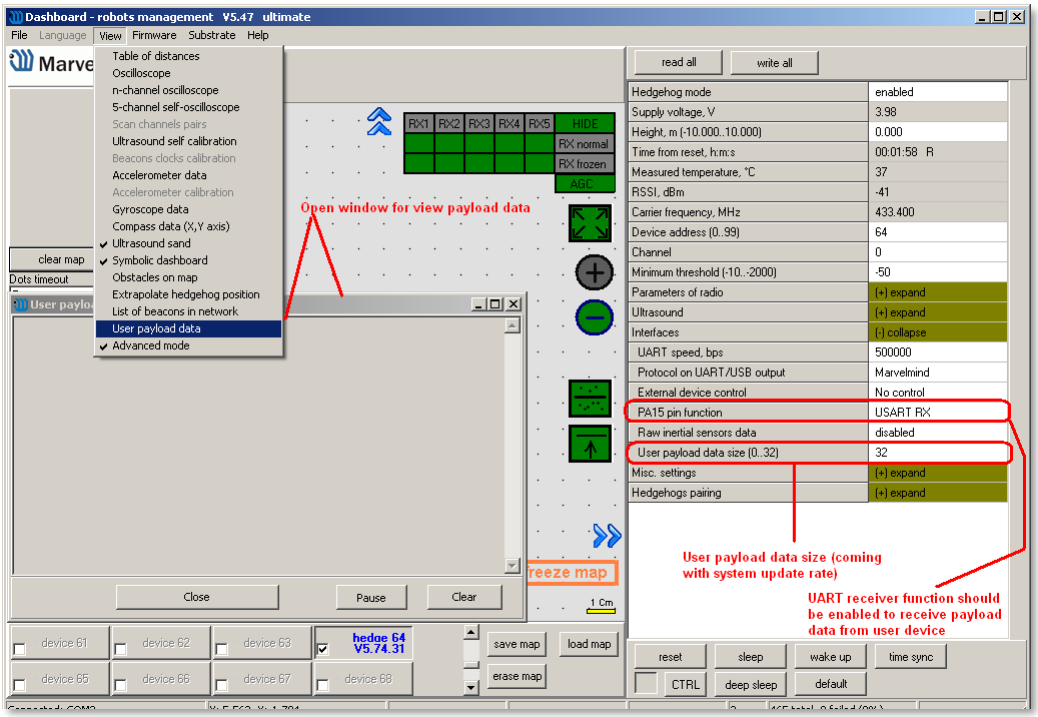
7.4 Load and save map

Save Map/Load Map feature and buttons are active now. You can build a very complex map with submaps and save all settings for the map, submaps, and all beacons including their ultrasonic gain, triggers, etc.



7.5 Payload streaming

- Mobile beacon streaming user payload to modem. See the table with speed vs. payload



- All measurements were made with update rate setting 16 Hz. Real update rate is limited by distance, radio profile and payload data size.

System configuration	Radio profile kbps	User payload data per cycle, bytes	Real update rate, Hz	User payload maximum data rate (bytes per second)
2 stationary beacons 3 meters maximum distance	500 (FEC)	0	16	0
		32	16	512
	153 (FEC)	0	16	0
		32	16	512
	38.4 (FEC)	0	9	0
		32	8	256
	38.4 (no FEC)	0	14	0
		32	13	416
4 stationary beacons 11 meters distance (limitation distances auto)	500 (FEC)	0	14	0
		32	14	448
	153 (FEC)	0	12	0
		32	12	384
	38.4 (FEC)	0	6	0
		32	6	192
	38.4 (no FEC)	0	9	0
		32	9	288

7.6 IMU feature

- This function allows to increase data update rate received from ultrasound beacon with IMU due to sensor fusion up to 100 Hz, using inertial sensors (accelerometer, gyroscope)

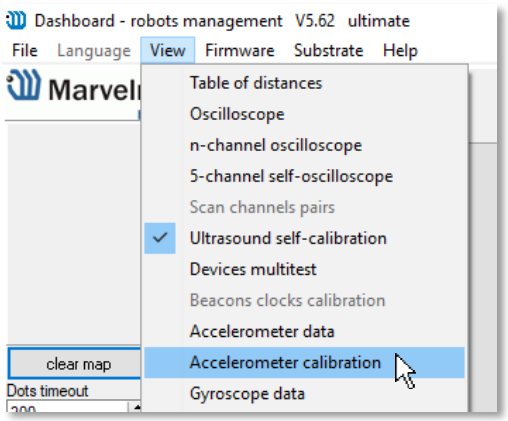
Required:

- Starter set
- Hedgehog with IMU
- SW and firmware version 5.85 or newer
- Ultrasound Update rate 4Hz or higher

Setup IMU feature:

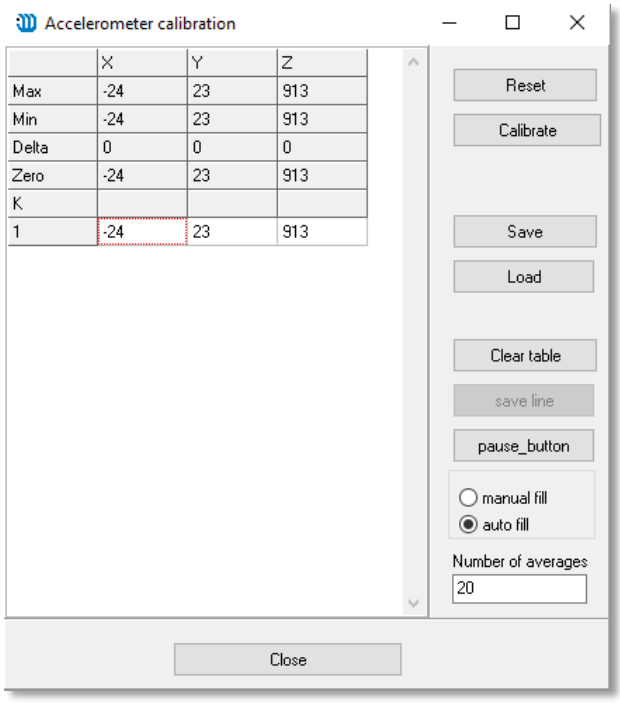
Accelerometer calibration

- Before you start use the feature check whether accelerometer has been calibrated
- Check if hedge was not calibrated before. Was damaged or fall down
- Put hedgehog on a flat surface (antenna directs up) and connect to your PC. Run the Dashboard



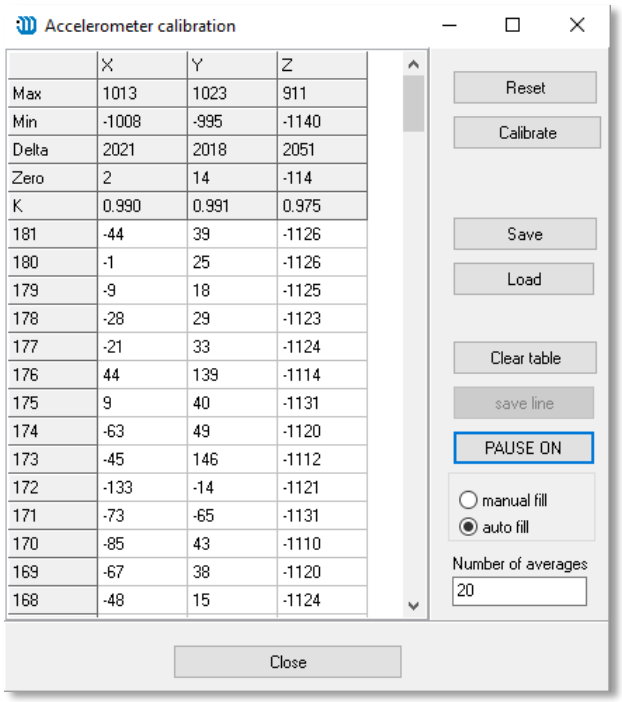
Go to **view => Accelerometer calibration** in open window click **autofill** and **clear table.**

After all values will refresh. Next, click **Pause (shift + space)**



Then take the beacon (hedgehog) and tilt it to each side towards the ground (like 6 times). rotate a little. You need to achieve x y z values:

- When antenna directs down **z ≈ - 1000** => antenna directs up **z ≈ 1000**
- So, one of the axis values always will be - + 1000. Others ⩽ **10** (preferably less 10, but 25 is also permissible)
- Every time before calibrating the hedgehog click **Pause**
- Accelerometer calibrator will choose the best value for each axe. At the end click **Calibrate** and close the window
- Calibration is needed to determine **g** value for each accelerometer axe



Start the system:

Setup the system as usual. It is described in paragraph Setting up the system

After the ultrasound tracking has started, select the hedgehog in the Dashboard, go to menu **Interfaces** (on the right) and enable **Processed IMU data**. After that, it is recommended to bring the hedgehog to real estate and press the ZERO IMU button (right-bottom) for additional sub-calibration of the gyro. After 5 seconds the hedgehog will begin streaming the processed IMU data.

Using Data in the Python Library Example:

Description of the protocol for streaming data: (link)

To work with data, you need to use some ready-made library, or develop your own software tools that can work with the described protocol.

Our company provides ready-made libraries for working with IMU in the following languages:

- python (link)
- c ++ (link)
- java (link)

An example with 3D imaging of a path on IMU with a frequency of 100Hz in real time, here: https://marvelmind.com/pics/marvelmind-imu-tracker.zip.

7.7 Player feature

This function is used to view the distance passed, the flight of the copter, etc. The player displays statistics on the maximum and average speed, the path traveled

1. Go to **File=>player**

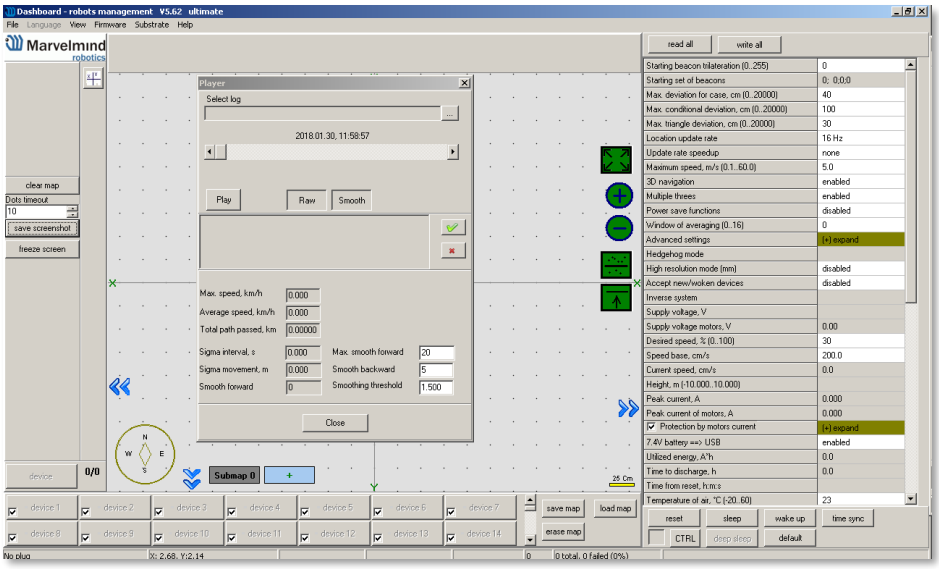
2. This is how starting player menu looks like

   Select log – opens save log file

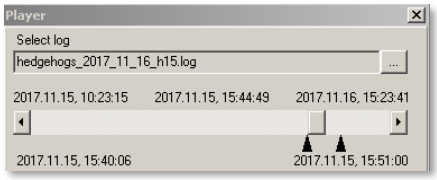
   Play – launch the player

   RAW – if clicked, player shows raw data

   Smooth – if clicked, player shows smooth data

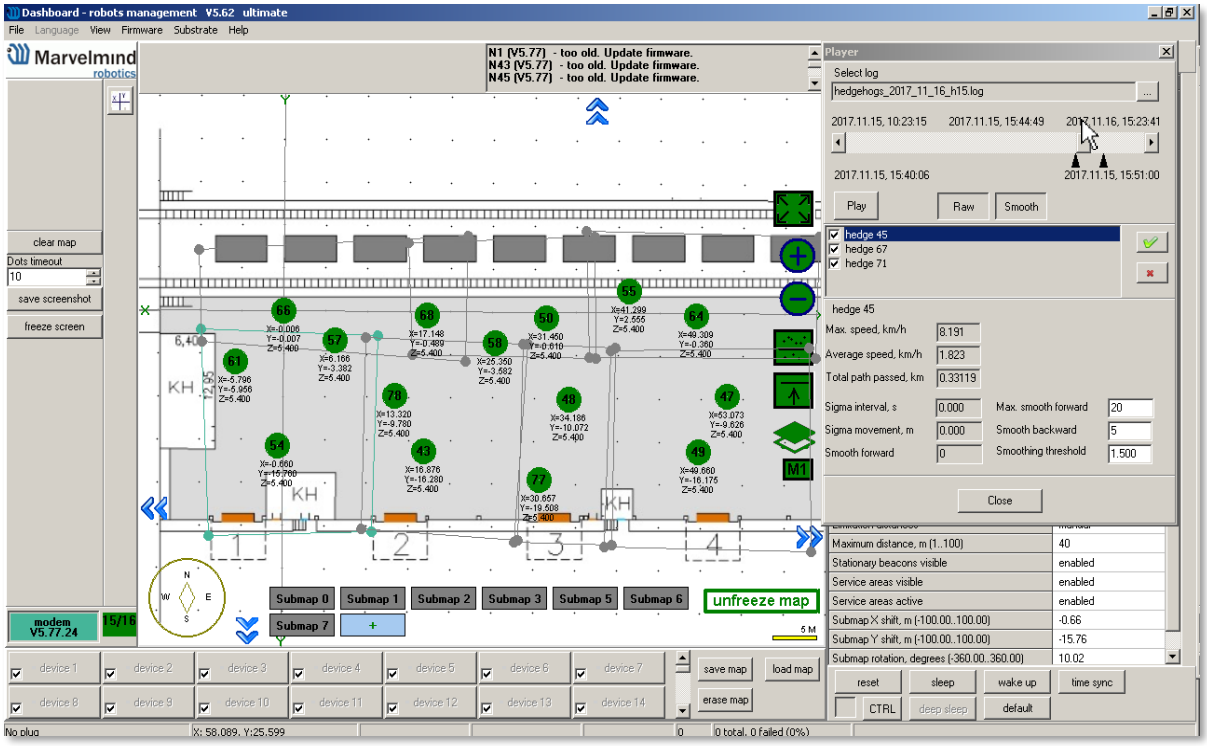


3. Now log is loaded. Important: for recording log file click **Save map** for saving all the beacons locations and attaching all the beacons to the log

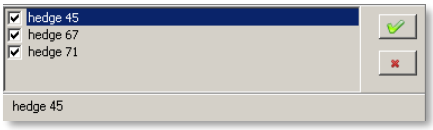


At the top of the player you can see 5 dates:

- Top row from left to right: starting log, current playing, end of the log
- Bottom row: beginning of the limited area, end of the limited area
- Limited area distance between black triangles under slider. You can move triangles and zoom, place cursor on the slider + mouse wheel
- Triangles limit the area in which player works and the statistics is calculated



4. In play mode: grey points – RAW data, blue – Smooth



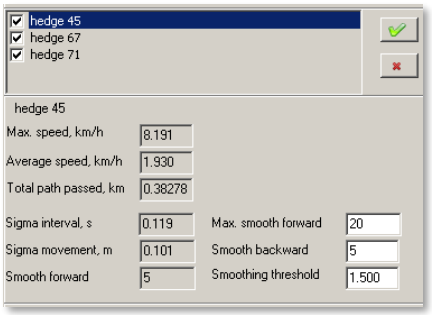
Choose the hedgehog will be displayed

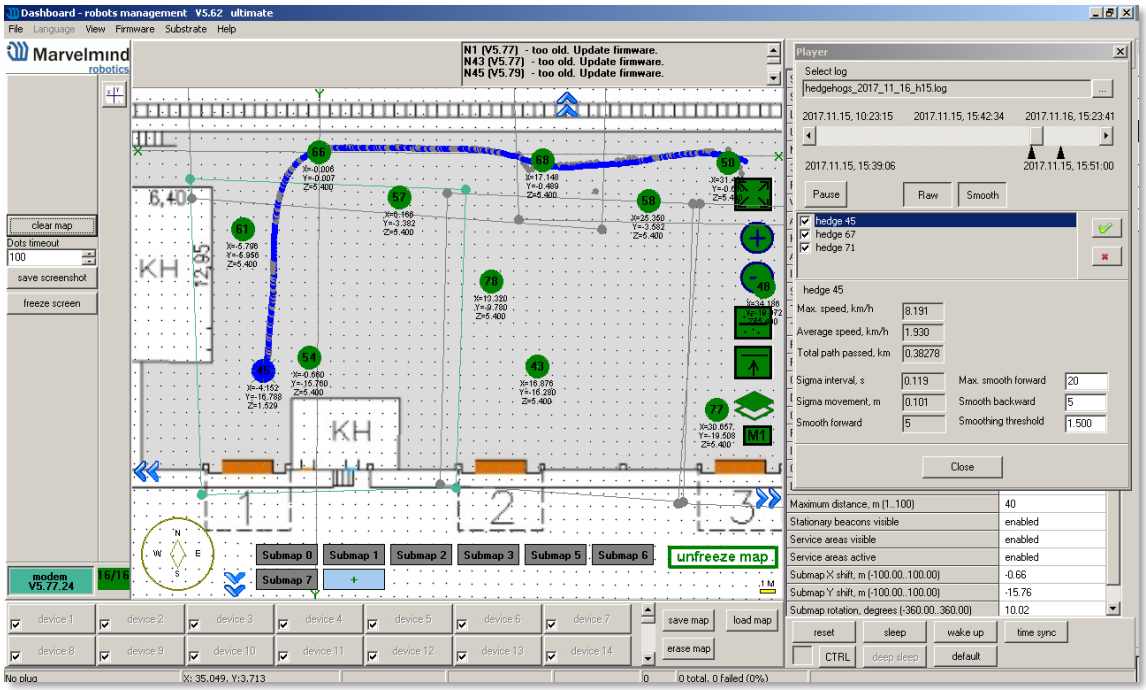
In the main Dashboard window, you can turn off displaying service areas and stationary beacons by clicking **Service areas visible**, **Stationary beacons visible**

Statistics displayed depends on chosen hedgehog in the list

Max smooth forward, **smooth backward** – depth smoothing

Smooth threshold - smoothing ratio.





7.8 CSV format

Current Dashboard version supports additional timestamp. See the attached screenshot, the UNIX time in milliseconds is the first value

In each line comma separated values, CSV:

- UNIX time in milliseconds (time since 1970.01.01)
- time from previous record in milliseconds
- time from running dashboard in milliseconds
- address of hedgehog
- X coordinate of hedgehog, meters
- Y coordinate of hedgehog, meters
- Z coordinate of hedgehog, meters
- address of stationary beacon
- raw distance from hedgehog to stationary beacon, meters

The last pair (beacon address, distance) is repeated n times equal stationary beacons quantity in the system.

```
1494780417562,16,12287484,10,5.643,-0.553,0.453,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417609,47,12287531,10,5.643,-0.553,0.453,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417625,16,12287547,10,5.643,-0.552,0.466,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417687,62,12287609,10,5.643,-0.552,0.466,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417703,16,12287625,10,5.643,-0.552,0.466,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417703,0,12287625,10,5.643,-0.552,0.466,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417750,47,12287672,10,5.646,-0.550,0.466,12,6.343,13,3.169,14,9.814,15,5.841,
1494780417812,62,12287734,10,5.646,-0.550,0.466,12,6.343,13,3.171,14,9.811,15,5.840,
1494780417812,0,12287734,10,5.646,-0.550,0.466,12,6.343,13,3.171,14,9.811,15,5.840,
1494780417843,31,12287765,10,5.646,-0.550,0.466,12,6.343,13,3.171,14,9.811,15,5.840,
1494780417875,32,12287797,10,5.642,-0.553,0.466,12,6.343,13,3.171,14,9.811,15,5.840,
1494780417875,0,12287797,10,5.642,-0.553,0.466,12,6.343,13,3.171,14,9.811,15,5.840,
1494780417937,62,12287859,10,5.642,-0.553,0.466,12,6.347,13,3.172,14,9.813,15,5.837,
1494780417968,31,12287890,10,5.642,-0.553,0.466,12,6.347,13,3.172,14,9.813,15,5.837,
1494780418031,63,12287953,10,5.649,-0.551,0.466,12,6.338,13,3.171,14,9.813,15,5.843,
1494780418078,47,12288000,10,5.649,-0.551,0.466,12,6.338,13,3.171,14,9.813,15,5.843,
1494780418140,62,12288062,10,5.642,-0.553,0.466,12,6.338,13,3.171,14,9.813,15,5.843,
1494780418140,0,12288062,10,5.642,-0.553,0.466,12,6.338,13,3.171,14,9.813,15,5.843,
1494780418171,31,12288093,10,5.642,-0.553,0.466,12,6.463,13,3.169,14,9.813,15,5.837,
1494780418203,32,12288125,10,5.642,-0.553,0.466,12,6.463,13,3.169,14,9.813,15,5.837,
1494780418265,62,12288187,10,5.648,-0.551,0.459,12,6.463,13,3.169,14,9.813,15,5.837,
1494780418312,47,12288234,10,5.648,-0.551,0.459,12,6.345,13,3.172,14,9.813,15,5.844,
1494780418375,63,12288297,10,5.651,-0.549,0.459,12,6.345,13,3.172,14,9.813,15,5.844,
1494780418375,0,12288297,10,5.651,-0.549,0.459,12,6.345,13,3.172,14,9.813,15,5.844,
1494780418390,15,12288312,10,5.651,-0.549,0.459,12,6.346,13,3.171,14,9.812,15,5.846,
1494780418421,31,12288343,10,5.651,-0.549,0.459,12,6.346,13,3.171,14,9.812,15,5.846,
1494780418468,47,12288390,10,5.651,-0.549,0.459,12,6.346,13,3.171,14,9.812,15,5.846,
1494780418468,0,12288390,10,5.651,-0.549,0.459,12,6.346,13,3.171,14,9.812,15,5.846,
1494780418546,78,12288468,10,5.651,-0.552,0.459,12,6.346,13,3.175,14,9.812,15,5.846,
1494780418546,0,12288468,10,5.651,-0.552,0.459,12,6.346,13,3.175,14,9.812,15,5.846,
1494780418593,47,12288515,10,5.651,-0.552,0.459,12,6.346,13,3.175,14,9.812,15,5.846,
```

8. Interfaces

Indoor “GPS” system supports many external interfaces that can feed measured location data to an external system (robot, copter, VR, etc.).

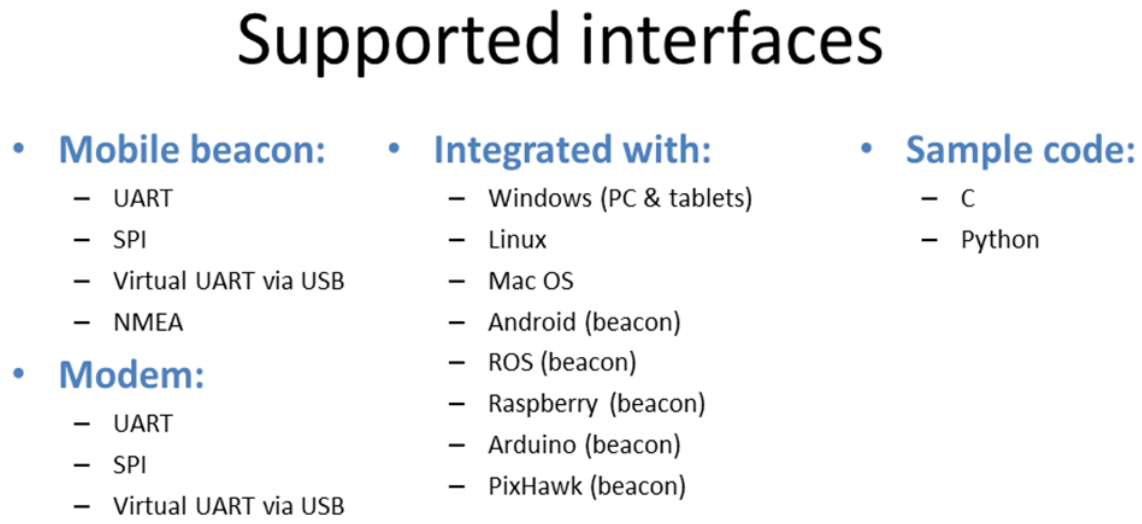
There are two different ways to obtain the mobile beacons’ location data from the system

1. From the mobile beacons
    - Each mobile beacon knows its own position and does not know the positions of the other mobile beacons
2. From modem/router
    - Knows position of every mobile beacon in the system

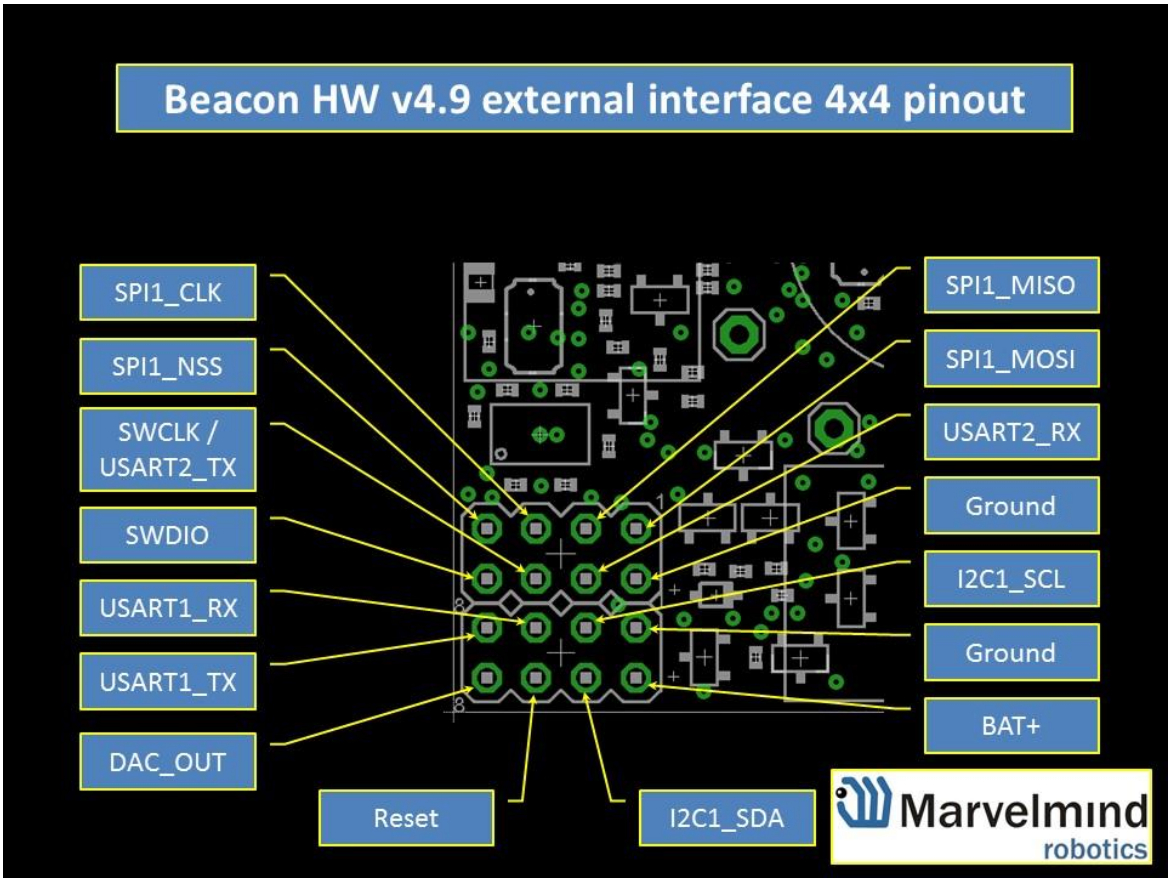
Data from the mobile beacons and from the modem can be obtained at the same time, if necessary

A list of the supported interfaces is shown below.

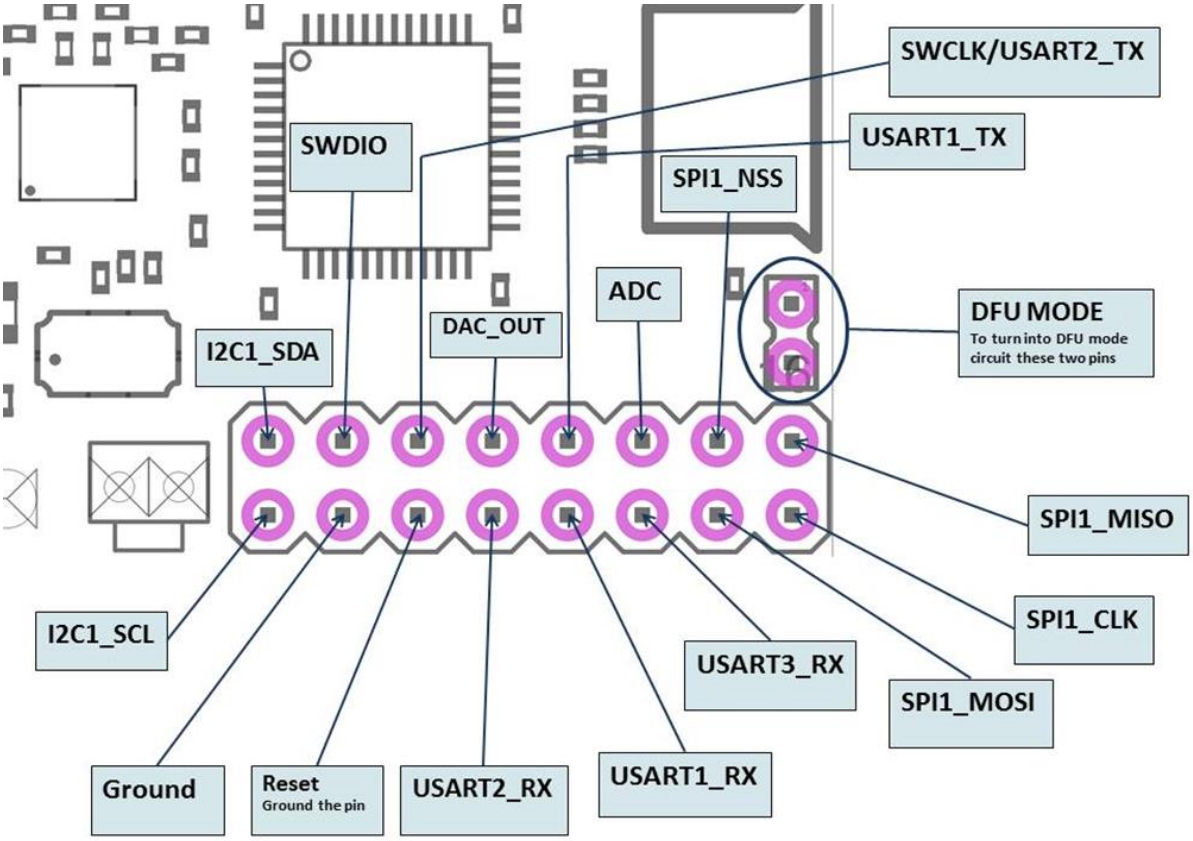
More information on the interfaces can be found here:
http://marvelmind.com/#Interfaces.



8.1 Beacon HW v4.9 external interface 4x4 pinout top view



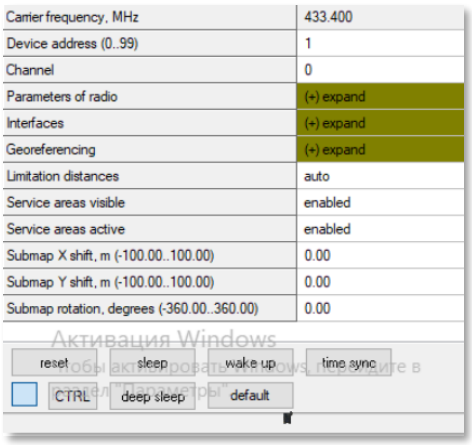
8.2 Modem HW v4.9 external interface pinout top view



9. Advanced system settings and optimization

Start using advanced settings only when you know what you are doing

If you ran into troubles, connect the beacon or modem to the PC via USB and use the **DEFAULT** button. It will upload “factory settings” to the board while keeping the device address untracked.



9.1 How to place beacons

Avoid placing beacons on long sound-conducting objects

This is a very rare but may happen in some special circumstances.

The best practice is to place beacons (stationary and mobile) in places that would not result in the transfer of ultrasound energy from the beacon's board/case directly to the place it is attached via a medium other than air. For example, solid attachment of a beacon to a long horizontal metal tube may result in the following:

- Sound emitted from the beacon propagates directly to the metal tube
- Propagation losses inside metal are much smaller than in the air Moreover, the tube may act as a low-loss waveguide
- If the tube is solid enough and long enough, there may be a weird effect where the receiving beacon receives the signal sooner than expected, i.e., sooner than the distance divided by the speed of sound in air. That happens because the speed of sound in metal is much higher than the speed of sound in the air. The ultrasound signal may even look stronger than the real signal propagated through the air due to the lower amount of losses of ultrasonic in metal than in the air
- It is good practice to place beacons on something relatively soft or something that does not conduct sound

Place beacons in a way that provides the proper ultrasonic coverage. It must be one beacon in the line of sight of minimum 2 beacons. Try to locate them under ceilings to avoid shadows, walls etc.

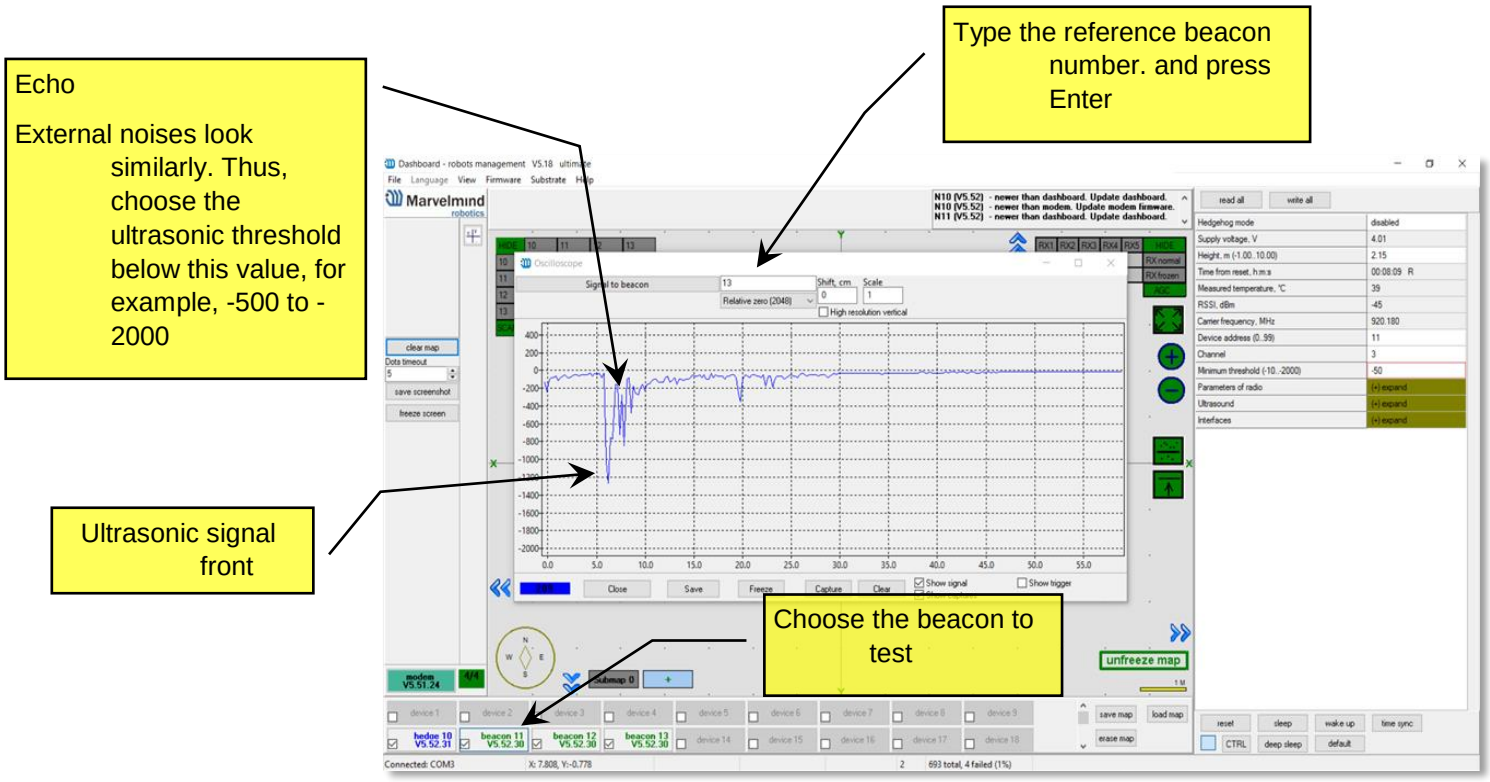
- Optimal settings for stationary beacons in small and big rooms
- Use 30–50 ultrasonic pulses for larger places and the default 5 pulses for smaller places
- Optimal settings for noisy environment

There are several ways to reduce impact:

- Mobile beacons can be placed very close to the source of noise without harm, but stationary beacons should be placed further from the noise because they are receiving the ultrasound, whereas the mobile beacon is emitting the ultrasound.

9.2 Using Oscilloscope

- Monitor ultrasonic signal from one beacon to another
- Use **Dashboard => View => Oscilloscope** to monitor ultrasonic signals from one beacon to another
- It is a very powerful tool, because it gives also information on the background noise, level of the signal, echo, etc. With this tool, it is easy to set up the proper ultrasonic threshold on the Dashboard.

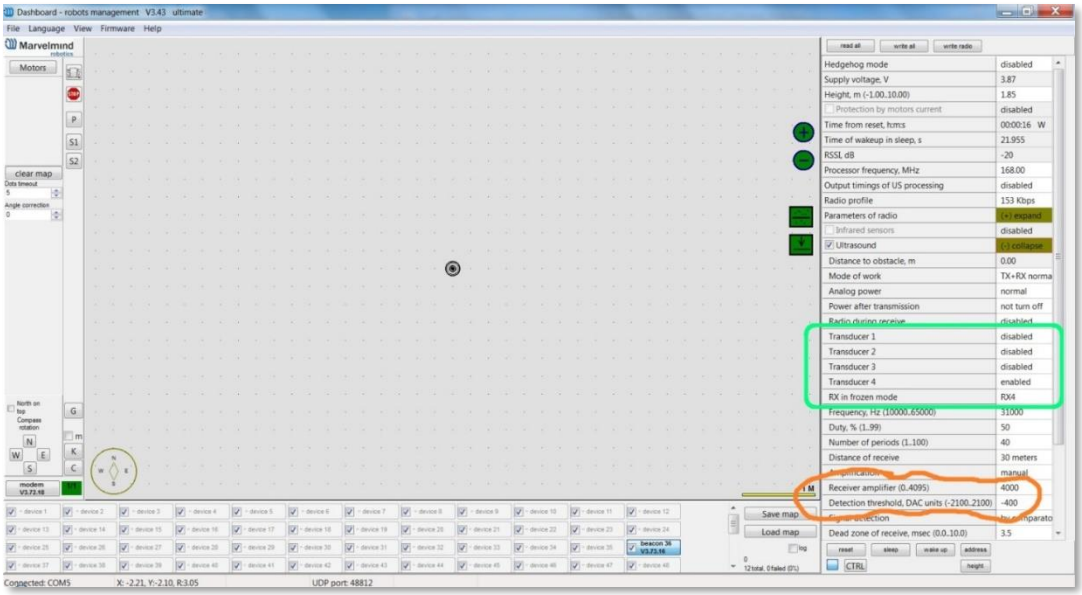


9.3 Proper ultrasonic signal detection

When external noise is high:

- Identify the source. Usual suspects:
- Ultrasonic-based volume or movement detection alarm systems
- Other robots using ultrasonic
- Parktronics
- Sources of very strong white or impulse noise (air guns, air press, cutters, vacuum cleaner, etc.)
- Rotors of drones/copters

- Marvelmind Indoor Navigation System uses proprietary 31kHz frequency for ultrasonic signal and employs additional filtering to combat external noise. This also makes the system rather immune against the “usual suspects.” However, if the external noise is too strong, its source is too close, or it’s emitting a strong signal on frequencies close to 31kHz or white noise, the system functionality can be affected.
- The best things to do in this case are to (1) identify the beacons that are affected. Usually, they are those that are the closest to the source of noise; (2) manually reduce the gain of the affected stationary beacons so that the signal from the mobile beacon would have a 1000–1800 amplitude. That would give the best signal-to-noise ratio. Don’t make the gain too high. The noise will be amplified, but the desired signal will be saturated and signal-to-noise ratio will be poor.
- The gain settings may be very non-linear. There is almost no change at 4000 to 3000. But around 2500, the gain starts reducing very quickly (1200 – for some HW versions). By setting the gain manually, it is possible to find the optimal gain to obtain the highest signal to noise ratio so the system can work even in very challenging external conditions.
- When the map is formed, only the mobile beacon is emitting, whereas stationary beacons are not. Thus, it does not matter how close the mobile beacon is to the source of the noise.
- But it matters how close the stationary beacons are to those sources. So select the positions of the stationary beacons accordingly - place them further from the sources of noise.



9.4 Using hedgehog.log file

- The system automatically records all measured positions in the hedgehog.log file that is stored in the same folder as the Dashboard.exe file
- The data is written in csv format; each line describes the position of one of the hedgehogs at a certain moment
- The line format is described here.

9.5 System accuracy evaluation

1) Accuracy of distances measurement.

   - Marvelmind navigation system can measure distances between beacons with accuracy of +/- 2cm if it uses correct ultrasound speed in measurements
   - The ultrasound speed depends of many factors: temperature of air, pressure, humidity and so on
   - The main factor is temperature. In temperature range of -20…+50 °C the speed of ultrasound changes on about 0.6 m/ (s* °C). It gives distance error about (0.6 / 340) *100% ~ 0.17%/ °C. So caused by incorrect temperature setting absolute error of distance measurement is 0.17% of real distance between beacons. For example, with distance 30 meters and 5 °C error, this gives 0.85%*30 ~ 0.25 meters' error. Marvelmind system allows to setup temperature of air in the system settings

2) Accuracy of position measurement.

   - Marvelmind system uses trilateration algorithm to calculate position by distances. The inaccuracy of position calculation is related to inaccuracy of distances measurement and to geometry of relative location of stationary and mobile beacons
   - Basic trilateration formulas are given in this article: https://en.wikipedia.org/wiki/Trilateration
   - As you see, the position of mobile beacons **X**, **Y**, **Z** is calculated from positions of 3 stationary beacons which are set by values of **d**, **i**, **j**. One of the beacons was shifted to (0,0) position to simplify formulas in the article. In formulas for **X**, **Y** we see **d** and **j** in denominators. This means that with low values of **d** and **j** small error of this value can cause large position error
   - Please see the picture of the beacons in the article - in more simple words, in means that if one of three beacons is close to line connecting other two beacons, it gives increased inaccuracy of locating mobile beacon
   - For example:
     - assume d= 10, i= 5, j= 0.1, r1= 7, r2= 7, r3= 4.8
     - We get x= 5, **y= 2.4375**, z = 4.25
     - If we suppose that j=0.101 (0.1 cm error), we receive x= 5, **y= -0.06**, z= 4.89
     - You see very large Y error
   - Another example for Z. Assume mobile beacon is relative close to plane of stationary beacons:
     - d= 8, i= 4, j= 6, r1= 5.02, r2= 5.02, r3= 3.01
     - This gives X=4, Y= 3.01169, Z= 0.36
     - If we suppose r3= 3.0 (1 cm error), we receive X=4, Y= 3.016, Z= 0.44. Error on Z is about 8 cm
   - Also, with r1= 5, r2= 5, r3= 3, Z will be 0. As you see, low change of distances causes large change of Z value near the plane.

9.6 Calibration of the accelerometer

To calibrate an accelerometer on your beacon with IMU, you can do following steps:

- Connect the mobile beacon via USB to the Dashboard

- Make sure that the beacon has IMU on board: open ***View / Accelerometer menu*** and ***view / gyro data***. In the presence of IMU graphics in these windows should display the angular velocity and acceleration when moving the mobile beacon (turn it in hands).
  Close the window of the accelerometer and gyro data

- Open the calibration window: ***View / calibrate the accelerometer***

- When calibrating, it measures the data of the free fall (gravity of the Earth) corresponding to each of the three axes X, Y, Z. The initial ones from these calculations remember the correction shifts indicated in the table as "Zero" and the correction factors indicated as "K"

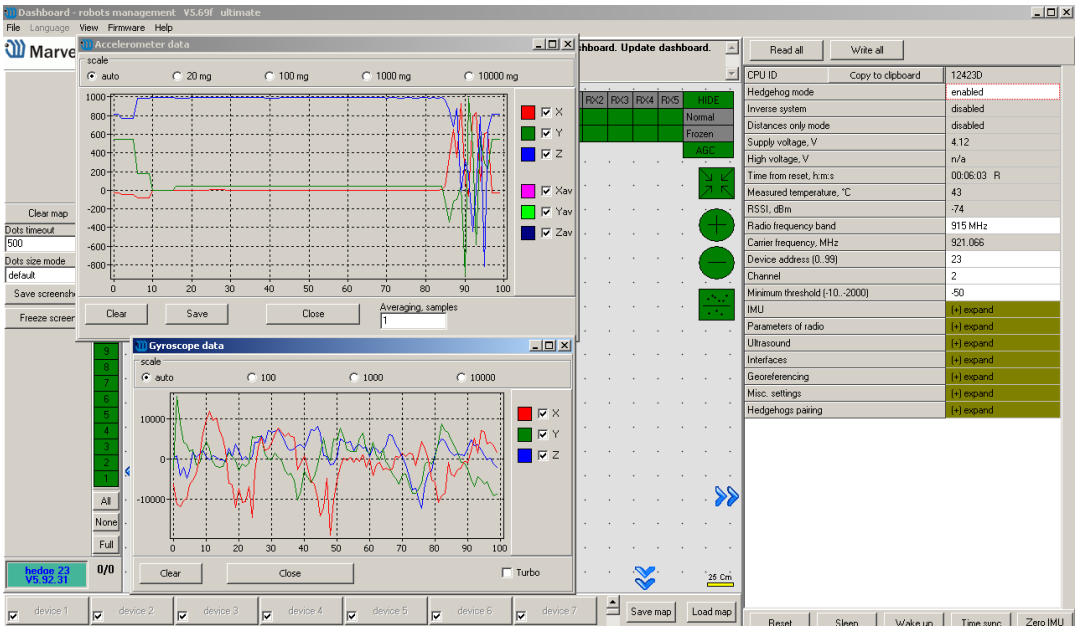
- The switch at the right bottom of the window should be in the **AutoFill** position

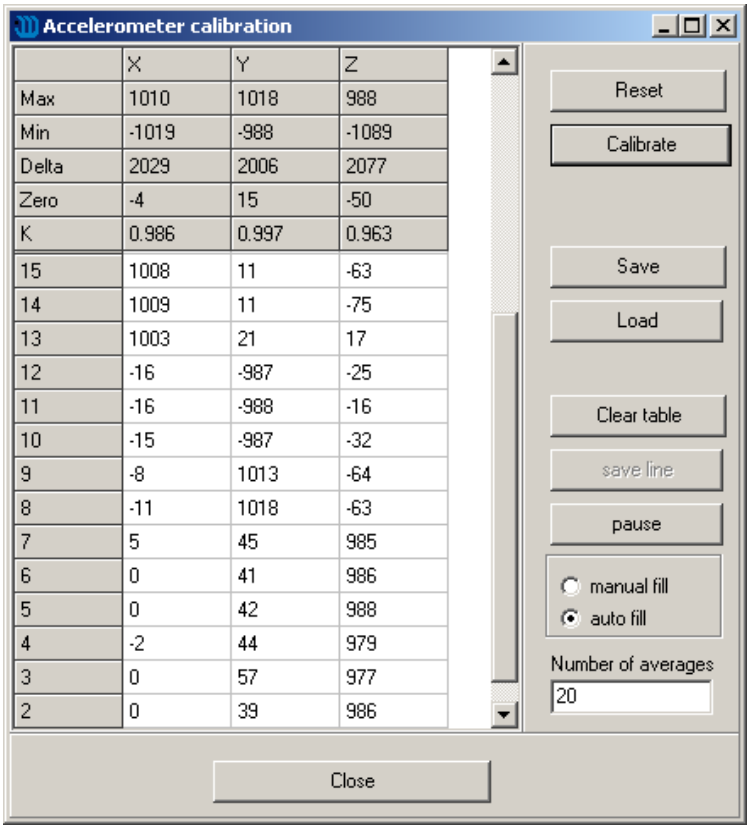
- Before starting the calibration, click the **Reset** button at the top of the window - zeroing the current calibration results

- To calibrate: slowly, without jerking, manually turn the beacon in each of the 6 positions and keep it still for 1-2 seconds:
  - The starting position - the beacon lies on the table; the antenna is pointing upwards (calibration Z +)
  - The beacon is turned upside down, the antenna pointing down (calibration Z-)
  - The beacon is on the end, the sensor RX1 is pointing towards the table (calibration Y +)
  - The beacon rests on the end, the RX3 sensor points toward the table (calibration Y-)
  - The beacon rests on the end, the RX2 sensor is directed towards the table (calibration X +). In order not to interfere with the USB connector, the beacon can be placed on the edge of the table, so that the cable hangs down
  - The beacon rests on the end, the RX5 sensor points toward the table (calibration X-)

- In each measurement, the readings of the accelerometer are corrected by Zero and K.
  At the end of the measurement of 6 points 7.1 ... 7.6, in the serviceable accelerometer Zero should be close to zero, and K close to 1, see the screenshot.
  If not - check if you forgot any of the points 7.1 ... 7.6.

- To save the results, click **Calibrate**.





	X	Y	Z
Max	1010	1018	988
Min	-1019	-988	-1089
Delta	2029	2006	2077
Zero	-4	15	-50
K	0.986	0.997	0.963
15	1008	11	-63
14	1009	11	-75
13	1003	21	17
12	-16	-987	-25
11	-16	-988	-16
10	-15	-987	-32
9	-8	1013	-64
8	-11	1018	-63
7	5	45	985
6	0	41	986
5	0	42	988
4	-2	44	979
3	0	57	977
2	0	39	986

9.7 Title reserved

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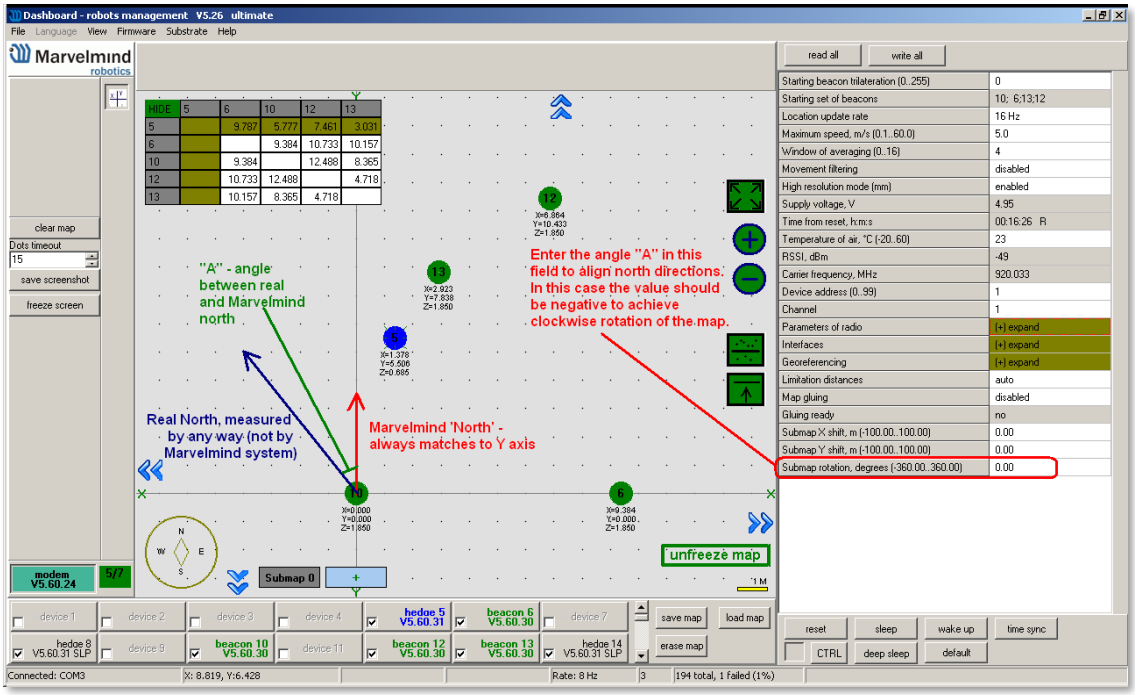
9.8 Settings to obtain correct north direction

- In some cases, it is necessary to obtain a correct north orientation of the map for NMEA output from Marvelmind system. For example, when using a Marvelmind mobile beacon as the navigation data source for Pixhawk installed on a copter, correct north is required for correct yaw control of the copter. The Marvelmind system cannot determine north automatically, so the user should make corrections after building and freezing the map. It can be done in one of two ways:

    1. Rotate the Marvelmind map using the dashboard, as shown on the attached screenshot
    2. You can also view the video: https://www.youtube.com/watch?v=AsYXrtg7aVU&feature=youtu.be

- Enter the angle correction (the angle shown on screenshot) on the Pixhawk side from the Mission Planner of APM Planner

- Refer to the parameter "BCN_ORIENT_YAW": http://ardupilot.org/copter/docs/parameters.html?highlight=bcn_orient_yaw



- Beacons may issue raw sensor data. To learn how to obtain this data, please check this protocol: https://marvelmind.com/pics/marvelmind_beacon_interfaces.pdf

- You can receive the data byte-by-byte and check for the required packet header

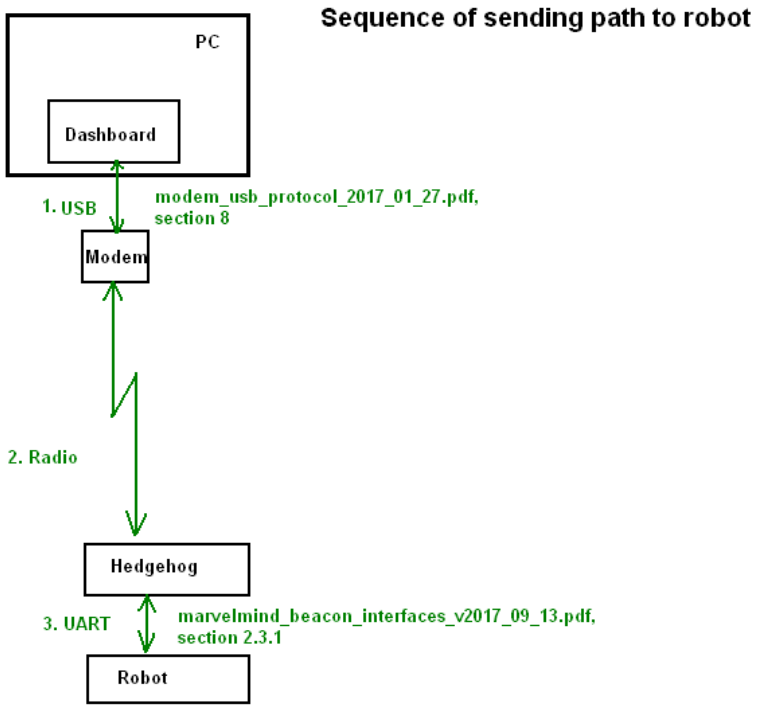
- See an example here: http://www.marvelmind.com/downloads/2017_02_08_C_example.zip.

9.9 Communication of Pixhawk with Marvelmind mobile beacon

The Marvelmind mobile beacon can be connected to Pixhawk (and to any other hardware or software that inputs GPS according to the NMEA0183 protocol). The mobile beacon can send GPS data via UART and USB (virtual UART) interfaces. For further explanation, please check out this document.

9.10 Sending path to robot

1. The dashboard sends request to modem via USB.
   Procedure of sending these requests in dashboard is shown on second screenshot.
   This format of request is described in section 8 of modem protocol:
   https://marvelmind.com/wp-content/uploads/2017/08/modem_usb_protocol_2017_01_27.pdf

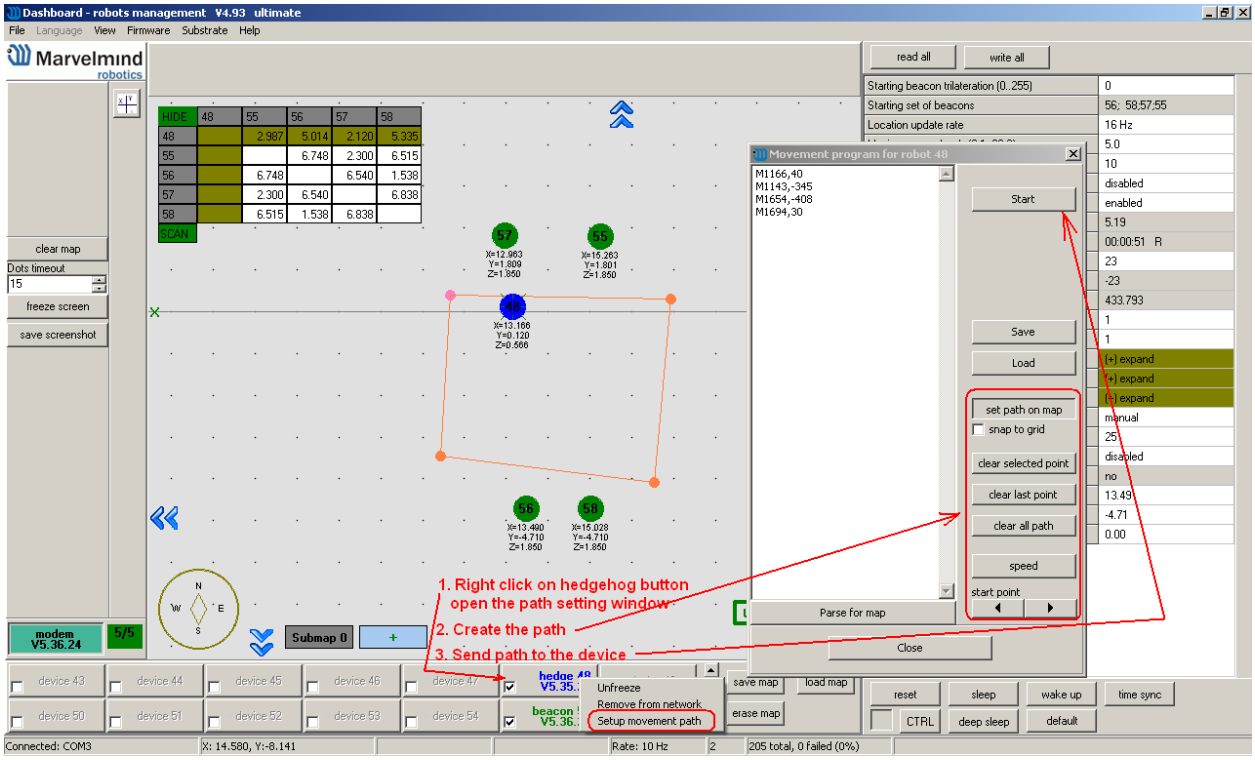


2. Modem transmits data to the hedgehog via radio, using our proprietary protocol

3. the hedgehog communicates with robot via UART. Hedgehog sends data according to section 2.3.1 of this protocol:
   https://www.marvelmind.com/pics/marvelmind_beacon_interfaces_v2017_09_13.pdf

   The robot should confirm receiving data by response packet shown in section 2.3

   This communication on the robot side is implemented in the Arduino example on our site. As you can see in the protocol, robot should not request the waypoints, the hedgehog will send the waypoints when they will be transmitted from dashboard. But robot should confirm receiving each waypoint by this packet:
   [0x03,0x47,0x01,0x02,0x00, <2 bytes of checksum>]

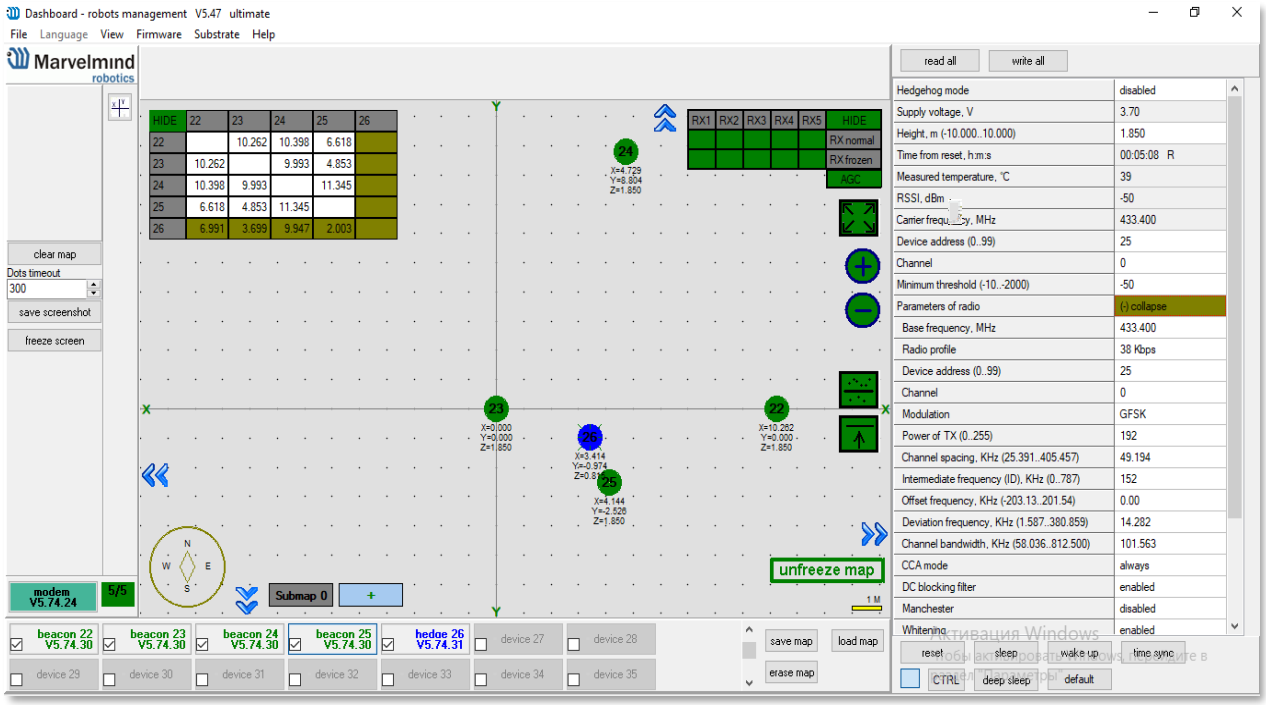


9.11 Proper ultrasonic coverage

The single most important requirement for the system to work well is to have proper ultrasonic coverage

Each sensor has an ultrasonic beam of ~90 degrees. Outside of that range, the emitting power and sensitivity drops quite rapidly. From the left, right, or back of the ultrasonic sensor, the signal is highly attenuated. Thus, it is crucial to provide proper ultrasonic coverage for the area where the robot will be moving.

- It is also very important to provide proper ultrasonic coverage to the stationary beacons when the map is being formed
- **Mobile beacon ("hedgehog" or "hedge") is designed to be placed horizontally**
- The mobile beacon has four horizontal and one vertical sensor, each covering its own sector. Together, they cover 360 degrees horizontally and 180 degrees in the upper hemisphere. The lower hemisphere is highly attenuated, so don't expect ultrasonic coverage in that area
- It is advised that the mobile beacon be placed as high as possible on the robot if the stationary beacons are above the mobile beacon. This minimizes shadows from other objects, people, etc.



- Example of proper positioning of the mobile beacon can be found here:

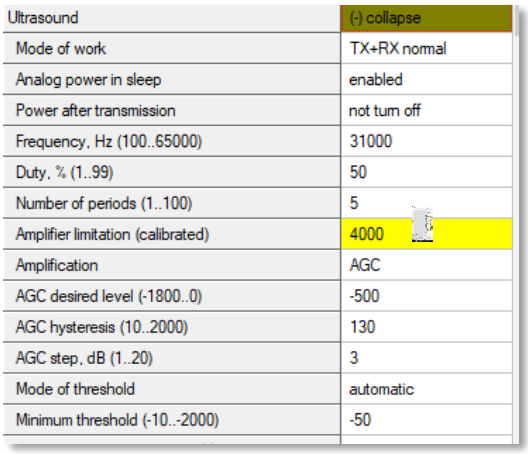
  https://youtu.be/PFgNPkLGCDk

- The beacon is placed horizontally and above other objects that can cast a shadow on the stationary beacons
- **Keep the radio signal's strength under control**
- The RSSI (Dashboard => right menu) of any beacon/modem must not be higher than -25dBm. Otherwise, the system may malfunction

It is recommended the distance between the modem and beacons be no less than 0.5–1m. Beacons can be placed as close to each other as needed. If a beacon is extremely close to the modem, disconnect the antenna from the beacon. Monitor the Received Signal Strength Indicator (RSSI). It must be in the range of -25 to -70dBm. An RSSI of less than -70dBm will work too, but packet losses may start occurring. The quality of the radio connection very much depends on external interference as well because the used band is ISM (either 915MHz or 433MHz) and there are numerous co-existing systems.

Use 30 - 50 periods (pulses) in settings instead of the default 5. Select:

Ultrasound settings => Number of periods



Ultrasound	(-) collapse
Mode of work	TX+RX normal
Analog power in sleep	enabled
Power after transmission	not turn off
Frequency, Hz (100..65000)	31000
Duty, % (1..99)	50
Number of periods (1..100)	5
Amplifier limitation (calibrated)	4000
Amplification	AGC
AGC desired level (-1800..0)	-500
AGC hysteresis (10..2000)	130
AGC step, dB (1..20)	3
Mode of threshold	automatic
Minimum threshold (-10..-2000)	-50

When you have large errors in position estimation (more than a 1m inaccuracy), use the embedded Oscilloscope on **Dashboard => View** to determine which stationary beacon is jammed

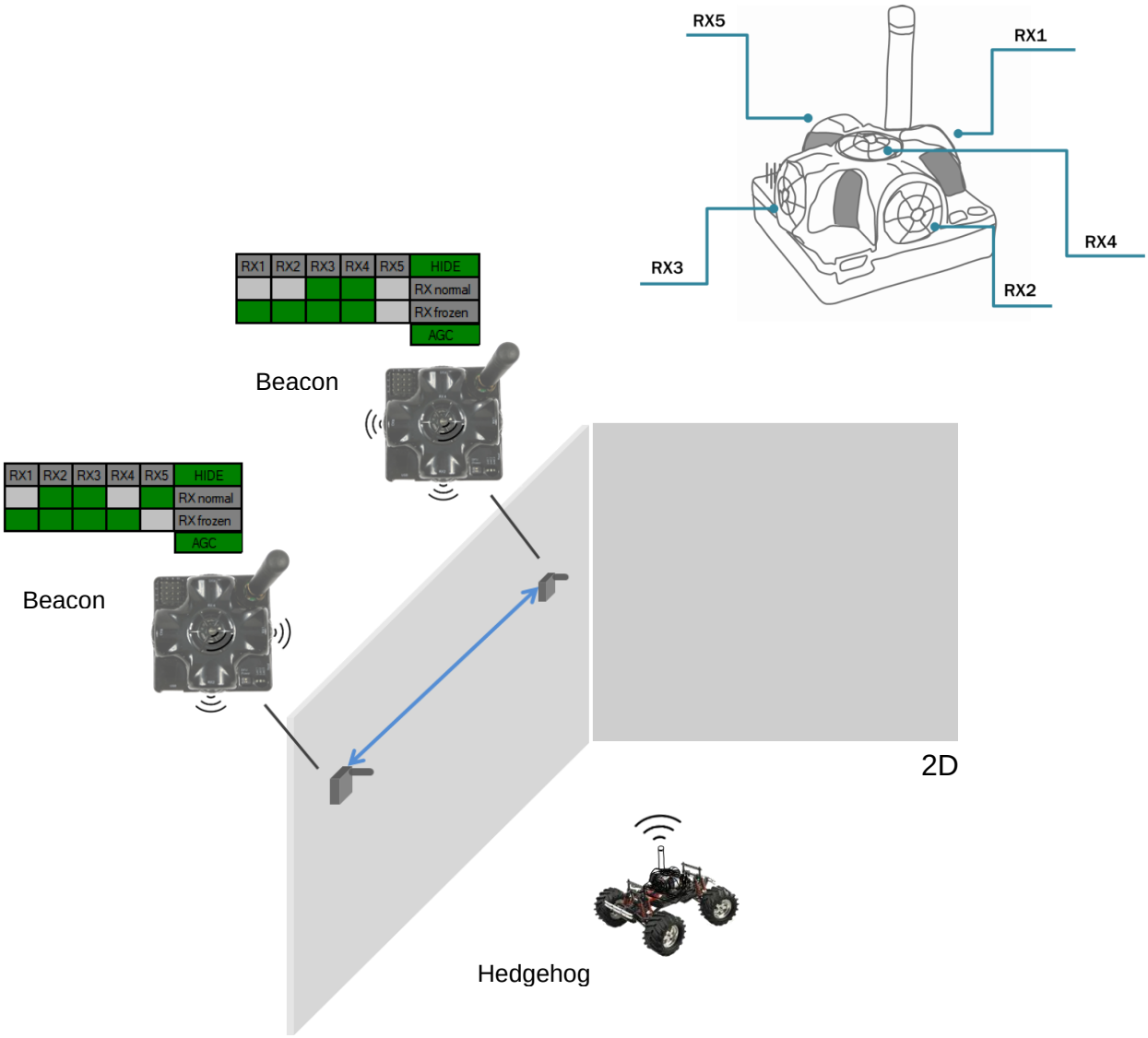
Reduce the gain of the ultrasonic manually depending on your system

- Multibyte numbers are transmitted starting from low byte (little endian format)
- Negative values represented as two's complement

For example:

- a 32-bit integer value '-100' is represented as FFFFFF9C (transmitted as sequence 9C, FF, FF, FF in little endian format)
- This value is detected as negative by '1' value of MSB and converted by subtracting 2^32: 0xFFFFFF9C- 0x100000000 = -0x64= -100.

9.12 Sensors settings: example for 2D and mobile beacon



Beacon 2

RX1 and RX4 emit ultrasound in normal mode for better ultrasonic signal exchange with Beacon 3. In frozen mode RX2 added as working sensor. The rest sensors are turned off

Changing sensors' settings could be found in the panel in the upper right corner of the Dashboard during your beacon is connected to the computer

Beacon 3

RX3 and RX4 emit ultrasound in normal mode for better ultrasonic signal exchange with Beacon 2. In frozen mode RX2 added as working sensor. The rest sensors are turned off

9.13 Powering beacons

Modes of operations

1. Stationary beacons powered from a clean source of +5V USB
2. Mobile beacon powered from a clean source of +5V USB from a robot
3. Operations based on internal LiPol 3.7V 1000 mAh cell

Typical power consumption in deep sleep mode is 50uA, which provides ~2 years of shelf time with a regular 1000mAh battery. The beacon can be woken up from deep sleep only by pressing HW **RESET** button

In regular sleep mode, the beacons wake up automatically every 2 seconds for ~20ms to monitor external calls from the modem/router. That causes some additional consumption, but it can still be left for several months in sleep mode

Active mode work time directly depends on the location update rate. For example:

- With the standard 1000mAh battery and 16Hz update rate, the expected work time will be 97h => 8 days (assuming a 12-hour working day)

With the extended 4300mAh battery and 1Hz location update rate, the expected work time will be ~5800h or 484 days (assuming a 12-hour working day).

Calculated beacon's work time in active mode vs. location update rate

				Location update rate, Hz			
Current cons., mA	Time, ms	Charge, mAh	h	1	4	8	16
23.0	15.0	0.000096	10434783	2899	725	362	181
0.05	12.0	0.000000	6E+09	1666667	416667	208333	104167
42.0	7.0	0.000082	12244898	3401	850	425	213
0.10		0.000000	10000	10000	10000	10000	10000

				Location update rate, Hz			
				1	4	8	16
				Expected working time			
Standard battery	1000	mAh	Hours	1352	376	192	97
			Days	56.3	15.7	8.0	4.0
			1/2-days	112.7	31.3	16.0	8.1
Extended battery	4300	mAh	Hours	5814	1618	824	416
			Days	242.2	67.4	34.3	17.3
			1/2-days	484.5	134.8	68.7	34.7

10. Frequently Asked Questions

Please check this forum for more information. Here we will answer the most common questions

1 What is the proper way to place the beacons?

- The actual distance between beacons must be ≤ 30 m. Provide the line of sight from one beacon to minimum two others

2 How far can beacons be located from modem?

- In the open space the distance from the modem to the beacon can reach several hundred kilometers

3 What if hedgehog shown as **orange** circle or **transparent** inside in the Dashboard?

- **Blue** - normal mode and confident tracking
- **Orange** - system provides the best location data possible, but confidence is lower, than blue
- **Colorless / transparent** - usually, means lost radio packets or no ultrasound coverage

4 What is the obstacle for ultrasound?

- The real obstacles for ultrasound are walls (concrete), glass, metal. If you need to cover a multiple-floor territory you can use our Submap feature in which case the tracking will not be interrupted

5 How the system works in very low and very high temperatures?

- The optimal conditions for the system is 0 ºC - 40 ºC

6 Are beacons resistant to explosions, dust, dirt, water, noise?

- - Low-frequency noise (motor noise, industrial equipment) does not interfere with the normal operation of the system
- - We now working on IP67 version of beacon. It can work underwater at a depth of one meter up to half an hour. It will be fully resistant to dust, t will have protected housing and sensors

7 Is ultrasound harmful for human?

- We are surrounded by ultrasound impact. For example: parktronic, automatic doors, security alarms. Ultrasound is not harmful as you used to think

8 What is the time of delay between positioning the object and respond?

- The delay is directly proportional to the update rate. For example, if update rate is 16 Hz delay is 60 ms

9 What if losing hedgehog after 0.6 m

- By default, the service area for mobile beacons is limited and mobile beacon not positioning far from stationary beacons.

- The limit is 1.5x times the maximum distance between the stationary beacons. To expand the service area, please follow the instructions shown in the attached screenshot. Notice that positioning the mobile beacon far from stationary beacons and close to their plane may result in increased positioning error because of bad geometry of measurement

10 how to define IMU or not IMU beacon?

- Check white sticker on the box and on the beacon's bottom /IMU - with IMU
- Connect beacon via USB: Dashboard => View => Accelerometer data

11 Can we use none-IMU beacon as mobile beacon or not?

- Yes, you can (https://www.youtube.com/watch?v=A4aRsjH2-_E)

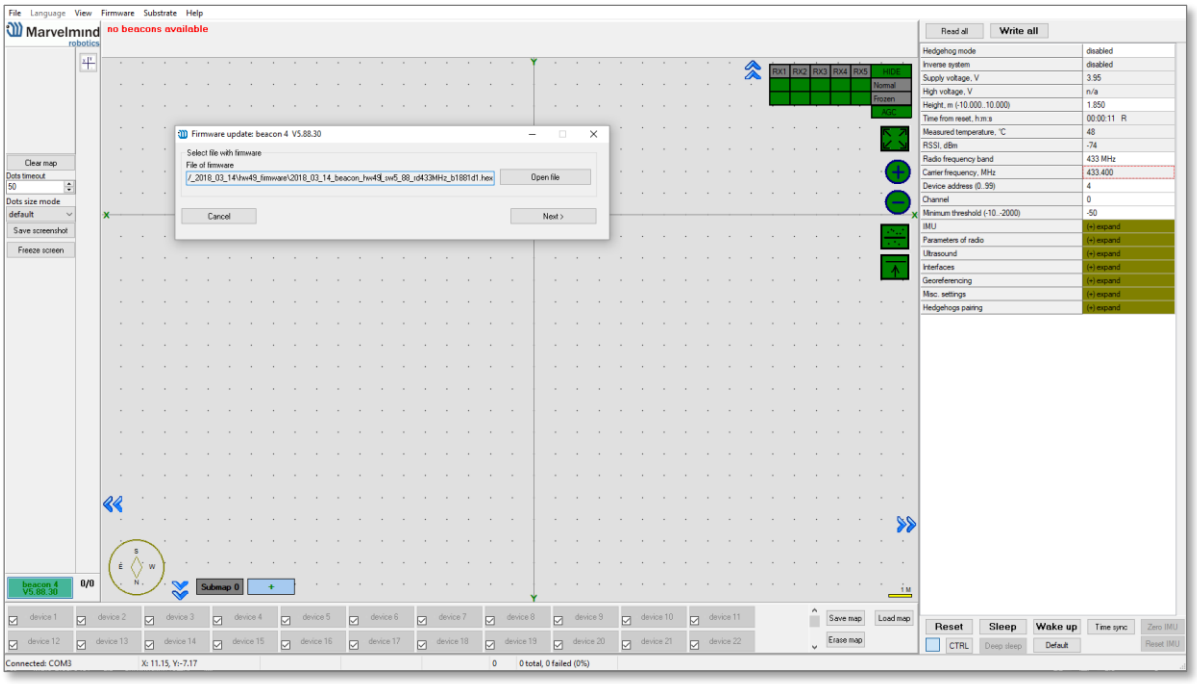
12 What is the reason to choose 915Mhz vs 433Mhz?

- The 915MHz version is designed for the US, Canada and Americas in general. The ISM band (license-free band for industrial, science and medical applications) in those countries is 915MHz
- In Europe, it is 433MHz

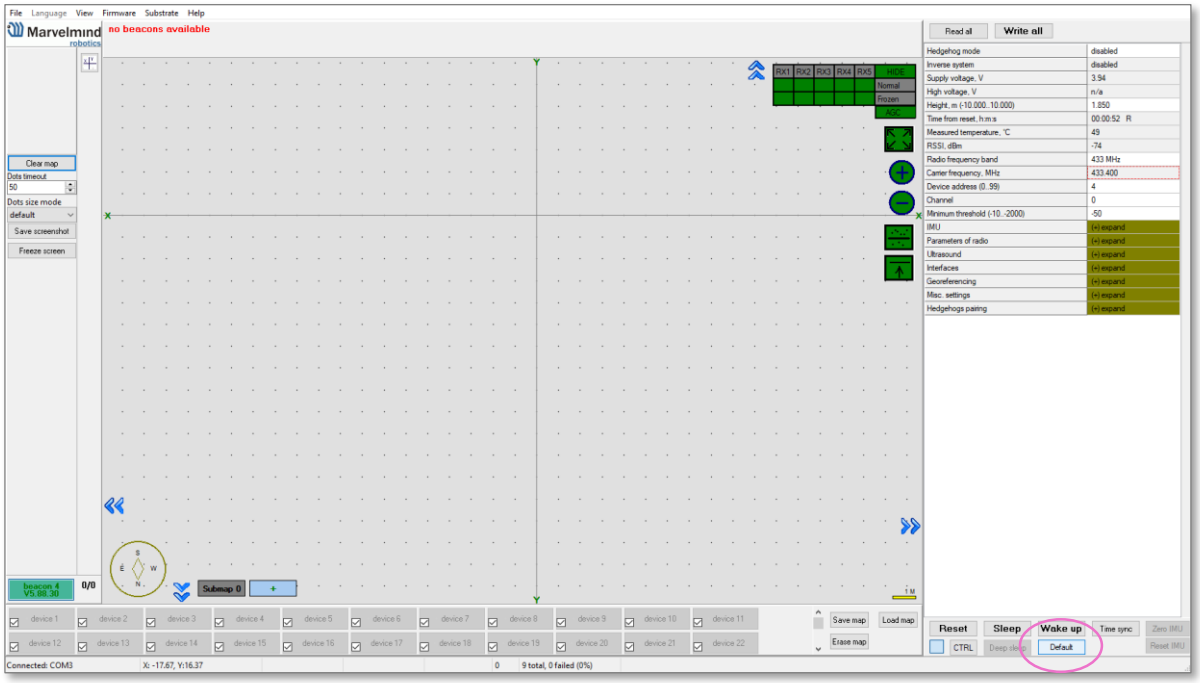
11. Troubleshooting

If you have any problems with the system, follow this simple steps:

- Update SW on modem and beacons



- Now, connect all beacons and modem one by one and press Default button in the Dashboard (When updating the SW, please, press Default button to make sure that beacons really have default settings. Otherwise, modem may be calling on a wrong channel or something)



12. Contacts

For additional support, please send your questions to info@marvelmind.com