RADAC
level, tide and wave monitoring

WaveGuide Onboard Explosion Proof

User Manual

WaveGuide Onboard Explosion Proof
User Manual

Applicable for product number:
WG5-OB-EX

Related to software versions:
wob 5.1

Version 5.1-1
1st of Dec. 2018

CE

Radac B.V.
Elektronicaweg 16b
2628 XG Delft
The Netherlands
tel: +31(0)15 890 3203
e-mail: info@radac.nl
website: www.radac.nl

RADAC
level, tide and wave monitoring

Preface

This user manual and technical documentation is intended for engineers and technicians involved in the software and hardware setup of the WaveGuide 5 Onboard system, Explosion Proof version (WG5-OB-EX).

Note

All connections to the instrument must be made using shielded cables. The shielding must be grounded at both ends of the cable. Please refer to Chapter 2 for more details regarding wiring and cable specifications.

Legal aspects

The mechanical and electrical installation must be carried out by trained personnel with knowledge of the local requirements and regulations for installation of explosion-proof equipment in hazardous areas.

Radac BV disclaims any responsibility for personal injury or damage to equipment or property caused by:

- Deviation from any of the prescribed procedures.
- Execution of activities that are not prescribed.
- Neglect of the general safety precautions for handling tools and use of electricity.

The contents, descriptions and specifications in this user manual are subject to change without notice. Radac BV accepts no responsibility for any errors that may appear in this user manual.

Additional information

Please do not hesitate to contact Radac or its representative if you require additional information.

Contents

Introduction

The WaveGuide Onboard is a highly accurate wave and waterline monitoring system for use on floating vessels. The system is robust, easy to install and explosion proof.

The WaveGuide Onboard includes two built-in sensors:

- A radar sensor that measures the distance to the water surface.
- An inertial measurement unit (IMU sensor) allows for motion compensation.

The WaveGuide radar is a low power X-band FMCW radar that measures the distance to the water surface with an accuracy of < 1 [cm]. The IMU sensor measures acceleration and hence requires a band-pass filter and a double integration cycle to obtain translation. The position of the water surface is obtained by subtracting the calculated translation (IMU) from the measured distance to the water surface (radar).

Filtering, integrating and aligning the raw data signals causes a 100 to 120 [sec] delay in calculating resultant heave data. That in turn is further processed to provide wave height parameters and wave spectra.

The measurements and calculated parameters are stored on the system and made available to the user via a web-based interface or as a stream of UDP messages.

This manual describes the Explosion proof version of the WaveGuide Onboard system. Please refer to the Radac website for all other manual versions.

Warning
Do not use the instrument for anything else than its intended purpose.

This manual consists of 4 chapters. Chapter 1 provides safety and security related information. Chapter 2 specifies the WaveGuide radar positioning criteria for optimal measurement quality and illustrates the mounting and installation procedure. Chapter 3 describes the commissioning of the system via the user interface. Chapter 4 explains data processing, data presentation and data distribution.

Please refer to Appendix 1 for a list of measured and calculated parameters. And to Appendix 2 for specifications, information about certification and environmental conditions applicable to the WaveGuide Onboard system.

Chapter 1

Safety and Security

1.1 General

For the correct and safe installing of this product, it is essential that all personnel follow generally accepted safety procedures in addition to the safety precautions specified in this document.

1.2 Safety Conventions

1.2.1 Warnings

The following warning box is used within this document to urge attention in order **to prevent personal injuries** or dangerous situations.

Warning
Carefully read the message in the warning boxes.

1.2.2 Cautions

The following caution box is used within this document to urge attention in order **to prevent damages to the equipment**.

Caution
Carefully read the message in the caution boxes.

1.3 Safety Instructions

The WaveGuide is a radar based level gauge for measuring wave and water-level information in offshore environment, lakes and rivers.

Warning
Only use the instrument for its intended purpose.

1.3.1 Safety

The mechanical and electrical installation shall only be carried out by trained personnel with knowledge of the requirements for installation of explosion proof equipment in (potentially) an explosive atmosphere. The entire installation procedure shall be carried out in accordance with national, local and company regulations and standards.

Warning - Risk of Explosion

Use only Explosion proof (Ex d) compound (due to > 2 [Liter] & IIB) cable glands or conduit seals, depending on local requirements.

Warning - Risk of Explosion

Cables and cable glands for at least 80 [°C] shall be used! Improper installation of cable glands, conduits or stopping plugs will invalidate the Ex approval of the WaveGuide. The use of stopping plugs on thread adapters is strongly advised against, as this may create unsafe Ex d characteristics.

Warning - Risk of Explosion

All lid bolts must be fastened with a torque of 30 [N·m] or 22 [lbf·ft] to prevent danger of explosion!

Caution

To comply with the IP66/IP67 requirements the blanking elements, threaded adapters, cable glands and their interface with the housing must also comply with IP66/IP67 requirements.

Warning - Risk of Explosion

To avoid risk of dangerous amounts of electrostatic charging, clean the instrument only with a damp cloth.

1.3.2 EC Declaration of Conformity (for EU)

See the EC declaration of conformity shipped with the device.

1.3.3 Additional Information

If you require additional information, contact Radac or its representative.

1.4 Liability

Radac disclaims any responsibility for personal injury or damage to equipment caused by:

- Deviation from any of the prescribed procedures.
- Execution of activities that are not prescribed.
- Neglect of the safety regulations for handling tools and use of electricity.

The contents, descriptions and specifications in this user manual are subject to change without notice. Radac accepts no responsibility for any errors that may appear in this Installation Guide.

Caution

Modification to the instrument may only be carried out by trained personnel that are authorized by Radac BV. Failure to adhere to this will invalidate the approval certificate.

1.5 Labels

Figure 1.1: Example of identification label.

1.6 Personal Safety

Warning

In hazardous areas it is compulsory to:

- use personal protection and safety gear such as a hard hat, a fire-resistive overall, safety shoes, safety glasses and working gloves.
- Avoid possible generation of static electricity.
- Use non-sparking tools and explosion-proof testers.
- Make sure no dangerous quantities of combustible gas mixtures that are present in the working area.
- Never start working before the work permit has been signed by all parties.

Note

The emitted microwave energy is far below acceptable limits for exposure to the human body. A maximum radiation of 0.1 [mW/cm^2] is generated.

1.7 Warnings and Cautions

1.7.1 General

Warning

Make sure that all power to the instrument is switched off before opening the covers of the WaveGuide radar. Failure to do so may cause danger to persons or damage to the equipment. Also, all the covers must be closed before switching on the power.

1.7.2 Tools

Warning

Treat the flange surface of the cover and the housing with care. Keep the flange surface free of dirt. The O-ring must be present and undamaged.

Warning

Use non-sparking tools and explosion-proof testers. Use suitable explosion-proof tools (e.g. testing devices)!

1.7.3 Working Environment

Hazardous Zone

Warning
POTENTIAL ELECTROSTATIC CHARGING HAZARD
Avoid the generation of static electricity. Electrostatic charge/discharge of the device from/to a person or a tool could ignite a surrounding hazardous atmosphere.

Safe Zone

Warning
Make sure that no explosive gas mixtures build up in the working area.

1.7.4 Required Skills

Warning
The technician must have technical skills to be able to safely install the equipment. The technician also must be trained to work in accordance with the national requirements for electrical equipment in hazardous areas.

1.8 Electrical

1.8.1 Commissioning and Maintenance

- The entire installation procedure must be carried out in accordance with national, local, and company regulations. The entire electrical installation shall be carried out in accordance with the national requirements for electrical equipment to be installed in hazardous areas.
- All wiring entries must be closed using the correct thread type such that the approvals are not invalidated. For installations using cable glands, use Ex d compound barrier glands. For installations using conduits, each conduit must be sealed within 18 inches of the enclosure.
- Improper installation of cable glands, conduits or stopping plugs invalidates the Ex approval of this device.
- Make sure that the housing of the device is properly bonded to the Protective Earth (PE).
- The temperature of the device's coupling due to local heat sources (e.g. contents of a tank or power dissipation) may not exceed a temperature of 80° [C].

- Cables and cable glands for at least 80° [C] (176° [F]) shall be used, unless ambient temperature is known to be always less than 50° [C] (122° [F]).

1.8.2 Grounding

Warning
Make sure the housing of the device is properly connected to the ground reference! Make sure the electrical resistance of the ground connection is below the maximum prescribed by local requirements!

1.9 Accordance with Regulations

1.9.1 Explosion Safety

ATEX
II 1/2 G Ex d IIB T6 Ga/Gb or Ex d [ia Ga] IIB T6 Ga/Gb
according to KEMA 07ATEX0010 X

IECEx
Ex d IIB T6 Ga/Gb or Ex d [ia Ga] IIB T6 Ga/Gb
according to IECEx KEM 07.0003X

1.9.2 Compliance to RED

This device complies with the Radio Equipment Directive. The device does not cause harmful interference and accepts any interference received. For more information please refer to the EC declaration of conformity shipped with the device.

Chapter 2

Radar positioning and installation

2.1 Positioning

For obtaining the best results from a WaveGuide Onboard the following radar positioning criteria must be taken into account:

- It is advised to choose a mounting position such that the WaveGuide radar beam is free of large reflecting obstacles (the beam of the F08 antenna has a 5° [deg] half top angle as shown in Fig. 2.1). The minimum horizontal distance between the radar and any obstacle in the beam's path should be at least 10% of the vertical distance between the radar and the obstacle. This does not only include horizontal objects in the beam's path but also vertical structures.
- Any structure that the WaveGuide radar is mounted to might have some influence on the wave flow around it. Hence, it is advised to mount the radar at a position facing the mean wave direction so that the radar can measure the least disturbed water surface. In most cases the ship's bow provides the optimal mounting position but as each vessel has a unique shape, it is the user's responsibility to carefully identify the best position for mounting the WaveGuide radar.
- The reference level for the mounting height of the radar is shown in Fig. 2.1.
- Figure 2.2, shows the polarization plane of the signal emitted from the radar antenna. If the WaveGuide radar is mounted close to a large vertical wall, then the radar should be mounted such that the polarization plane is parallel to the wall. That is to minimize the effect of the wall on the propagation of the signal. Nevertheless, the horizontal distance between the radar and the wall should comply with the previous criteria.
- A vertically mounted radar (0° [deg] tilt angle) results in optimal performance. But if necessary the WaveGuide radar can be mounted with a maximum tilt angle of 15° [deg] (tilted to face the direction away from the structure it is mounted on).

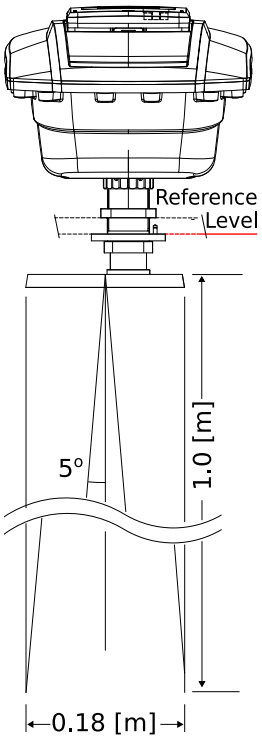


Figure 2.1: The 5° [deg] half top angle of the F08 antenna beam and the reference level for mounting height measurement.

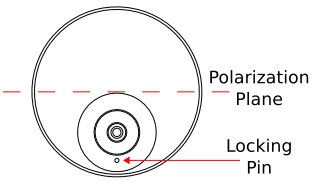


Figure 2.2: Top view of radar antenna and its polarization plane.

2.2 Installation

To facilitate the mounting of the WaveGuide radar, an optional mounting plate is available upon request (Part no. WG-MP-EX). Figure 2.3 shows a sketch of the optional mounting plate and its dimensions.

The mounting plate can be fixed to two horizontal beams (Fig. 2.4). The length of the beams must take into account the minimum horizontal distance between the WaveGuide radar and any obstacles in the path of the radar signal (as explained in the radar positioning criteria). Each beam must have 2 holes either 200 or 270 [mm] apart depending on the intended orientation of the mounting plate.

It is advised to mount the horizontal beams first. Then to attach the mounting plate to the horizontal beams and finally to mount the WaveGuide radar to the mounting plate. Mounting the radar is done by mounting the radar antenna to the mounting plate and then mounting the radar housing to the antenna.

Radac can provide an optional dual-purpose wrench/spanner (Part no. WG-EX-tool). One end of the wrench (Fig. 2.5) is an open-end wrench that can be used to tighten the antenna to the mounting plate. While the other end is a pin wrench that can be used for tightening the radar housing to the antenna. Upon request, Radac can supply an optional frame (Part no. WG-MH-EX) that allows for mounting the WaveGuide radar and mounting plate at angles 0, 5, 10, 15 and 20 [deg] away from vertical (see Fig.2.6). The radar mounting plate (Part no. WG-MP-EX) is included with this frame as well as brackets to allow mounting the frame to a handrail.

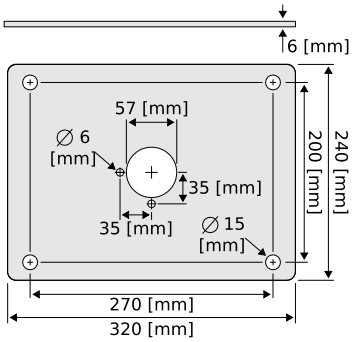


Figure 2.3: Optional mounting plate for the WaveGuide radar (Part no. WG-MP-EX).

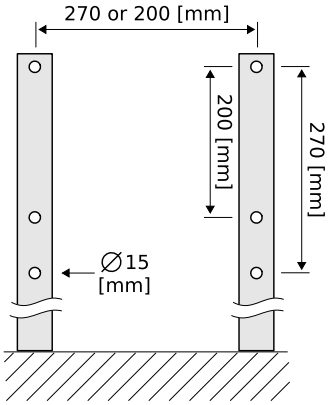


Figure 2.4: Top view of the horizontal mounting beams.

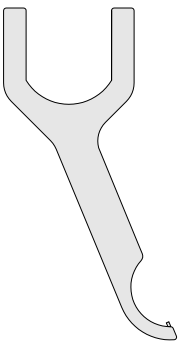


Figure 2.5: Optional wrench that allows mounting of the WaveGuide radar (Part no. WG-EX-tool).

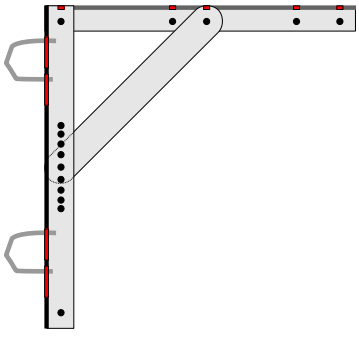


Figure 2.6: Optional frame that allows mounting of the WaveGuide radar at different angles (Part no. WG-MH-EX).

2.3 Cable

When selecting a cable for use with a WaveGuide system, the following requirements must be used:

- Two wires for power transmission. The choice of power supply will influence the diameter and insulation thickness of those wires.
- Four wires for data transmission. The use of an Ethernet data connection necessitates the use of four twisted-pair wires (22-24 [AWG] and minimum insulation thickness of 0.245 [mm]).
- The cable must be shielded and can have a maximum length of 80 [m].

Upon request, Radac can supply an optional cable that complies with the WaveGuide system requirements for power and data transmission.

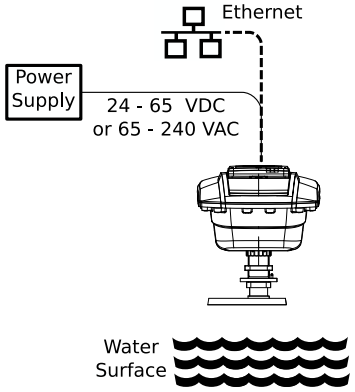


Figure 2.7: Block diagram of the Waveguide Onboard system.

2.4 Gland

Depending on local regulations, this device can be connected by using glands, direct entry, or conduits

An explosion proof (Ex-d) compound cable gland (M20), plus a M20 to 3/4" NPT converter are supplied with each WaveGuide radar for use as a safe and watertight cable entry point. The supplied gland allows the installation of cables from 6.5 to 11.9 [mm] in diameter.

Two approved 3/4" stopping plugs are provided for sealing the unused cable inlets

Note

Instructions supplied by the manufacturer for installing the included cable gland are provided separately in its packaging.

Caution

The use of Ex-d certified materials of an inappropriate IP value or the improper installation of cable glands, conduits or stopping plugs will invalidate the Ex approval of the WaveGuide.

2.5 Housing

To access the WaveGuide radar case:

- Open cover A as shown in Fig.2.8.
- Open and remove cover B as shown in Fig.2.9.
- Use an 8 [mm] Allen key to loosen the 16 bolts of the housing. Make sure the 4 bolts on the side of the hinge are entirely screwed into the cover and do not protrude beyond the flange of the housing. Otherwise the flange of the housing can be damaged when closing the cover.
- Open the housing cover.

Figure 2.8: Cover A.

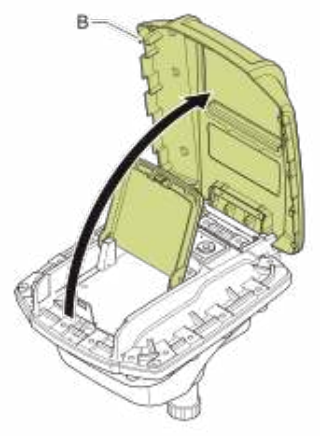


Figure 2.9: Cover B.

2.6 Wiring

The housing contains two sets of connector blocks as well as multiple ground connection points.

Figure 2.10 shows the connector blocks and the sequence of relevant poles. The poles number 00 labeled PSX:Vin-a/L and 01 labeled PSX:Vin-b/N are used to supply the system with either 24-65 [VDC] or 65-240 [VAC] power. The internal power supply is reverse polarity protected hence the polarity of the connected wires does not matter.

Please do take into account the voltage drop due to wire resistance between the power supply unit and the radar, the radar must at all times receive more than 21.0 [VDC]. For this reason, to be sure to stay within the limits, at longer distances it is advised to use a 36 [VDC] or a 48 [VDC] power supply.

The poles numbered 02, 03, 04 and 05 labeled RFL:Tx+, RFL:Tx-, RFL:Rx+ and RFL:Rx- relate to Ethernet data RJ45 pins 1, 2, 3 and 6.

Label	RJ45	Profinet Color
Tx+	1	Yellow
Tx-	2	Orange
Rx+	3	White
Rx-	6	Blue

Table 2.1: Ethernet wiring instruction.

Figure 2.10: Terminal compartment and connections.

The poles numbered 06 and 07 labeled RFL:LED+ and RFL:LED- are pre-connected to a status indicating LED. Upon powering the system the status LED will turn on and continue to shine while the system is starting up. When the startup process is completed and the system is running in normal mode the LED will blink every 4 [sec] (2 seconds on and 2 seconds off). In the case that a network connection can't be detected, the LED will blink every 1 [sec] (0.5 seconds on and 0.5 seconds off).

Additionally a reset function is implemented on poles 08 and 09 that are both labeled RFL:Reset, which should only be temporarily connected when resetting the radar to its factory settings or setting a fixed IPV4 address.

Note

Connecting the Reset poles for 0.2 to 2 [sec] during operation will cause the sensor to use the default IPV4 address 192.168.111.71 until the system is rebooted. Connecting the Reset poles for longer than 10 [sec] during operation will cause the system to reset to default factory settings and reboot.

The cable shielding must be connected to ground at both ends of the cable. Since there can be a potential difference between the ground at the radar and the ground at the processing unit, a capacitor (10 to 100 [nF]) should be used on one side of the cable between its shield and the ground.

Warning

Improper wiring can damage the radar's communication board. Always check that power is applied to the right connector before connecting it!

Warning

Safety depends on proper grounding of the radar housing. Check the resistance of the ground connection directly after installation. The measured ground resistance must be below the maximum prescribed by local grounding requirements.

2.7 Closing housing

Make sure that the flange is clean, that the O-ring is in place and not damaged. Then:

- Make sure to properly close the lid.
- Use an 8 [mm] Allen key to tighten the 16 bolts of the housing to a torque of 30 [N·m] or 22 [lbf·ft].
- Open the small cover (cover-A).
- Place the 2 hooks at one end of cover-B behind the axis on the housing and push it down carefully.
- Push down cover-A carefully.

Chapter 3

WaveGuide system commissioning

With all the wiring in place as described in the previous chapter, the system can be configured using the following steps (explained in the current chapter):

1. Connect the WaveGuide system to a computer.
2. Become an authorized user.
3. Configure the system.
4. Perform a system check.
5. Configure the distribution of data.

Step 1. Connect the WaveGuide system to a computer

Once the WaveGuide system is connected to a Local-Area-Network, communication can be done via the available web interface (Fig. 3.1). For this purpose any web browser with JavaScript enabled can be used.

Figure 3.1: The web interface of the WaveGuide system.

Note
A computer can be connected to the WaveGuide system directly using a network cable (a crossover cable is not required).

By default, during startup the WaveGuide system tries to obtain an IPV4 address by searching the Local-Area-Network for a DHCP server.

If a DHCP server is available and the WaveGuide sensor completes the startup process, its IPV4 address can be found using a Zeroconf browser such as Avahi or Bonjour.

If a DHCP server is not available, a temporary fixed IPV4 address can be set by connecting the two reset poles in the sensors terminal compartment for 0.2 to 2 [sec]. This will cause the sensor to use the default IPV4 address 192.168.111.71 until it is rebooted allowing the user to access and change the network settings to the desired fixed configuration. Note, that in order to access the user interface both the computer and the sensor must be on the same IPV4 address subnet.

The WaveGuide sensor homepage contains three main sections (Dashboard, Configuration and Status) as listed in Table 3.1.

Link	Description
Dashboard	Visualization of the measured data.
Configuration	Changing the settings and configuration of the system.
Status	System state overview and general information.

Table 3.1: Description of main sections in the user-interface.

Step 2. Become an authorized user

To modify the WaveGuide system's configuration you need to be an authorized user. Therefore, an authorization dialogue will appear when the user enters the configuration page.

The authorization will be valid for a duration of 30 minutes. However, the web browser may store the login name and password. In that case, the authorization data will be submitted automatically by the browser without a pop-up dialog. The default login password is "radac".

After successful authorization, the user can view and change settings. After submitting any new settings a reboot dialog will appear. The settings will not be effective until the WaveGuide sensor is rebooted.

Step 3. Configuration

The configuration page contains five sections as listed in Table 3.2.

Link	Description
Date & Time	For viewing and setting the system time.
Network	For viewing and changing the network settings.
Sensor	For viewing and changing the sensor specific settings and for viewing reflection diagrams.
Subscriptions	To set up data export over the network.
Data Logger	To view logged data.

Table 3.2: Description of configuration page sections.

Step 3.1: Set system date and time

In order to ensure accurate time stamping of the data, the WaveGuide system runs an NTP time service to automatically correct its system time to UTC time. For the NTP service to work, the system needs to be connected to the Internet, as it needs to be able to reach its default NTP servers.

In the case that the NTP servers can not be reached, it is possible to manually set the system date and time using the "Date & Time" menu (Fig. 3.2). Adjusting the date and time while the NTP option is selected is not possible as the time will be automatically corrected back to UTC time. If NTP is not used, the date and time are kept by a built-in clock. Please be aware that such a clock is not highly accurate and can drift over the years while the system is used, it is thus advised to use the NTP service.

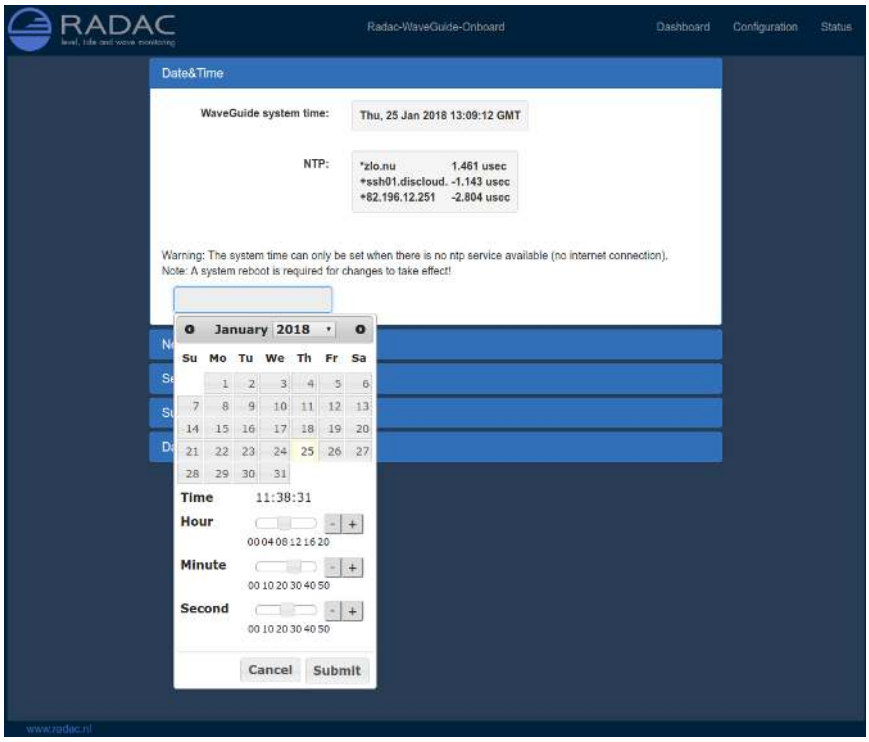


Figure 3.2: Setting the system time and date.

If the WaveGuide is not connected to the Internet but instead connected to a local network that includes a time server, then the WaveGuide system can be adjusted to synchronize time and date with the local time server. For more information regarding such an adjustment please contact Radac.

Step 3.2: Adjust network settings

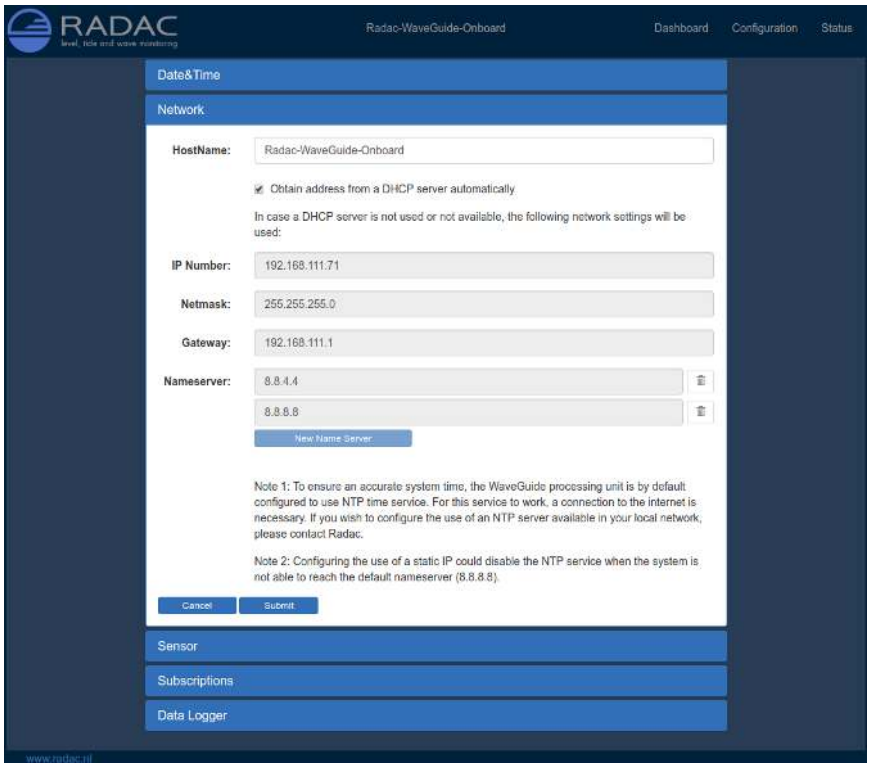


Figure 3.3: Adjusting the network settings.

The default IP address can be modified via the web interface (Fig. 3.3). It is advised to use the default settings, to automatically obtain the network settings from a DHCP server, and to ensure that the system will receive the same IP address from the DHCP server at all times. This setting provides the easiest setup and ensures the correct settings for the local network.

Note: use of a static IP could affect access to the NTP server if the system is not able to reach the default Nameserver (8.8.8.8).

Step 3.3: Sensor configuration

The WaveGuide Onboard is designed with a high level of flexibility in mind, to apply to every possible mounting situation. The sensor menu as shown in Fig. 3.4, allows the configuration of the parameters that are specific to the sensor mounting position.

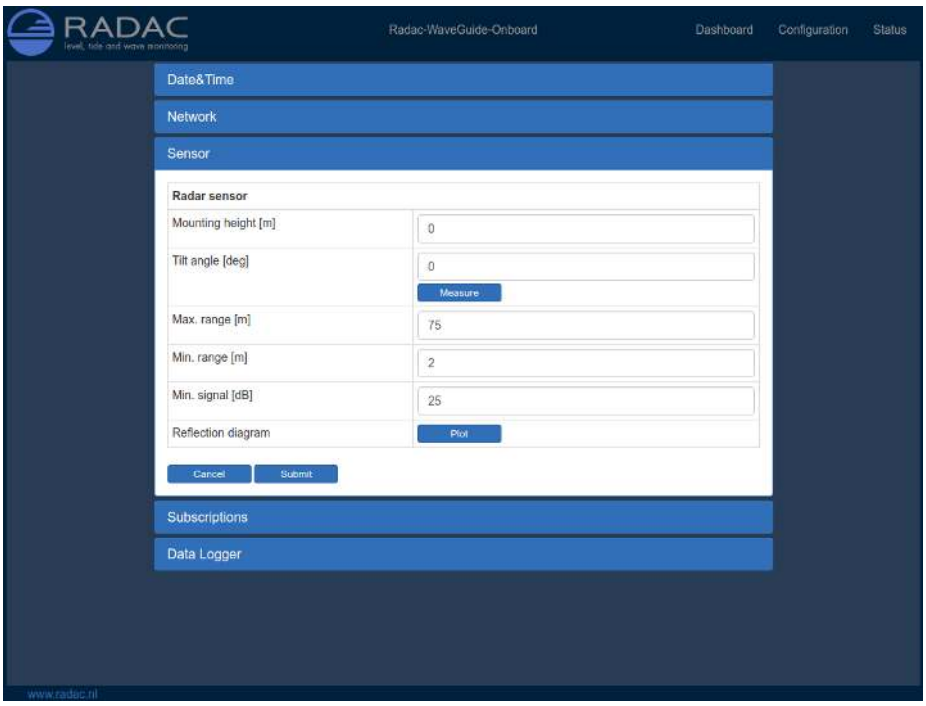


Figure 3.4: Setting sensor parameters (changes only take effect after the system is rebooted).

Mounting height
The mounting height is defined as the height of a radar above the reference water level in [m]. The reference point for measuring the height the radar is the top-side of the radar mounting flange (as shown in Fig. 1.1). By default, the mounting height is set to zero [m].

Tilt angle
The tilt angle, or the angular deviation from the vertical at which the radar is mounted, is measured in degrees. It can be used to tilt the radar reflection footprint away from the mounting construction. It is advised to only apply a tilt angle when it is really necessary.

Max. range
The range maximum is the maximum distance at which the sensor will detect the water level. In general there is no need to modify this parameter. Yet in some situations it is advised to set this parameter to a value lower than two times the distance from the radar to the lowest expected water level. This is to avoid detecting multiple echoes of the same measurement sweep.

Min. range
The range minimum is the minimum distance at which the sensor will detect the water level. This parameter is used to avoid spurious measurements and should be set depending on the installation location. If there are any nearby surfaces that can reflect the radar signal the range minimum should be set to a value higher than the distance to those reflecting surfaces. The range minimum parameter should not be lower than 2 [m] to avoid interference with the internal reflection in the radar antenna.

Min. signal
The signal minimum is the lower limit for the reflection signal power that will be considered in water level measurements. This parameter is by default set to 25 [dB], and should only be adjusted by an expert user.

Reflection diagram
The reflection diagram gives a snapshot of raw radar data in the frequency domain. The reflection diagram provides a useful insight in the quality of the reflection signal that is obtained by the radar.

After changing the sensor parameters for the radar, rebooting the system is required for the changes to take effect. The reflection diagram of the sensor should be checked to ensure that the water level measurement is within the defined limits (More information can be found in 'Step 4.2: Check the Reflection Diagrams').

Step 4. Perform system check

This section explains how to inspect the quality of measurements after configuring and rebooting the WaveGuide system (the start-up process can take up to 5 minutes).

Step 4.1: Check system information

The system information table can be reached through the status menu item on the top-right of the web interface. The system info page displays the communication status (as shown in Fig. 3.5). A communication status "INIT" indicates that the WaveGuide system is starting up. Once the system has started (a process that can take up to five minutes after power-up) the displayed status becomes 'OK'.

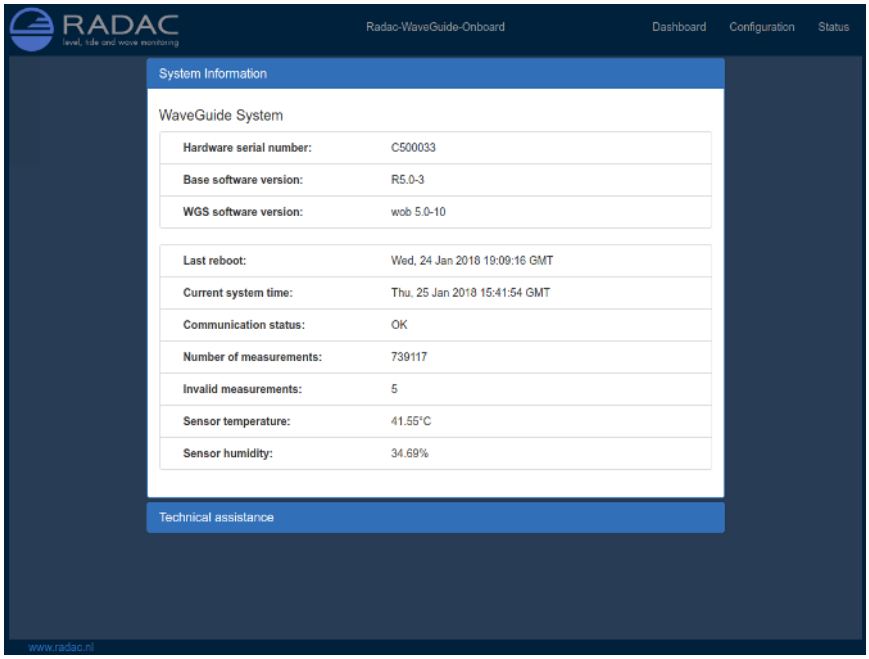


Figure 3.5: System information.

In the same table, the ratio between the number of performed and invalid measurements gives an indication of the system performance. When the system is set up in a correct manner, the number of invalid measurements should be below 10% of the number of performed measurements. However, during the start up and communication initiation processes the number of invalid measurements can grow to over 100 (temporarily increasing the ratio between invalid measurements and performed measurements). The number of invalid measurements will show a slow increase after the initial invalid measurements.

Step 4.2: Check reflection diagrams

The reflection diagram of the radar can be accessed via the sensor configuration page by clicking on the corresponding "reflection" button (Fig. 3.7).

A reflection diagram is a graphic representation of a single measurement, where the signal strength [dB] is plotted against the measurement distance [m]. A measurement consists of one up-sweep (increasing frequency, blue curve) and one down-sweep (decreasing frequency, red curve).

In some cases several peaks are visible in a reflection diagram as shown in Fig. 3.7. This is called a double reflection and is caused by the radar signal bouncing back and reflecting from the water surface for a second time. The signal processing takes this phenomenon into account such that it does not have a negative effect on the measurements.

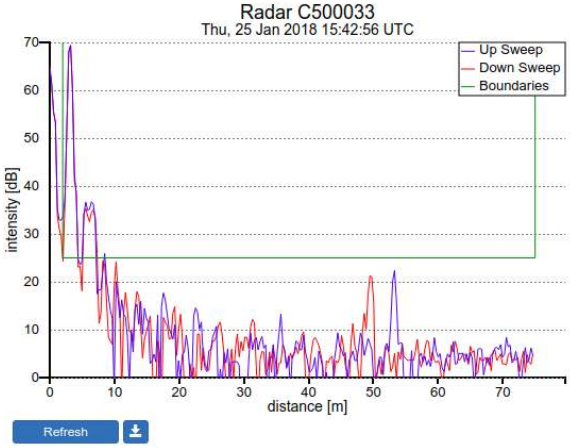


Figure 3.6: The reflection diagram gives a graphical representation of the radar signal received in a single measurement.

Based on the defined range maximum and minimum values, the WaveGuide system shows the applied boundaries using vertical green lines. A horizontal green line shows the minimum accepted reflection strength (the value set as the Signal Minimum [dB] parameter). The three green lines together form a region in which a measurement is accepted, and any result outside of it is ignored.

Step 4.3: Check measurements

The 'Dashboard' page, gives the possibility to view plots of different measured and calculated parameters. Please note that, as a result of calculations preformed some parameters are shown with a constant delay such as heaveIMU and heaveWOB (100 and 120 [sec] of delay). Also, that it takes up to 10 minute of gathering data to calculate and plot statistical parameters.

Please inspect the available heave graphs (Fig. 3.9) to visually confirm the measured data with reality.

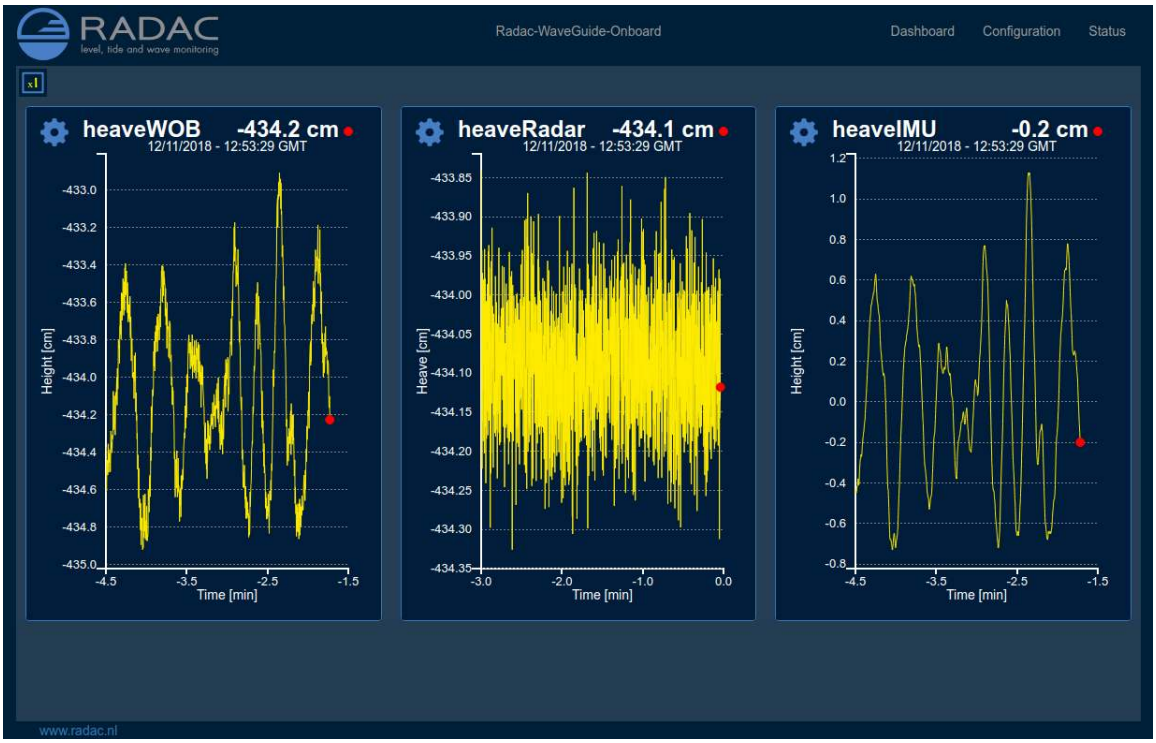


Figure 3.7: The dashboard page provides plots of the diferent measurements and calculated parameters.

Step 5. Configure distribution of data

The system can distribute measured and calculated data over the network by sending UDP messages to several addresses at the same time. In the 'Subscriptions' page under 'Configuration'(Fig. 3.8 and Fig. 3.9), the existing subscriptions can be removed or modified and new ones can be added. Simultaneous subscriptions are possible.

Figure 3.8: List of defined subscriptions.

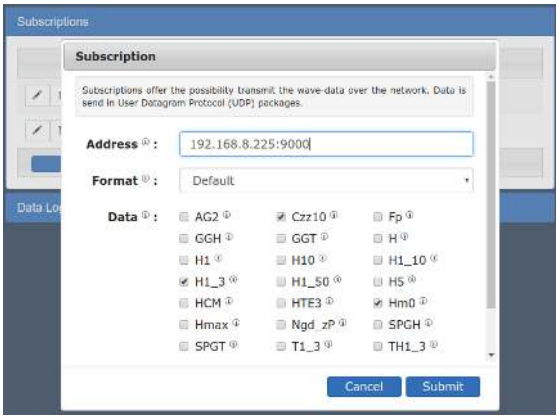


Figure 3.9: Subscriptions dialog.

The address for a data subscription over Ethernet should contain the IP address, a column and a port number. For example 192.168.111.103:8032.

The format of the transmitted message can be chosen from the drop-down menu. Five message format options are available, Default, Format01, Format02, Format03 and Format04.

After modifying or creating a new subscription, click the 'update' button and authorize the changes. This will change and store the settings and implement the subscription with immediate effect (no system reboot is required).

Default message format

The Default format starts a new line for each parameter in the subscription. The time used in the Radac format is Unix Epoch time in milliseconds (UTC time in milliseconds since 00:00:00 on the 1^{st} of January 1970). Each line in the Default format ends with a Line-Feed character (char10). When a parameter is disapproved or not available the string 'NaN' is inserted instead of the actual value (NaN stands for Not a Number). An example of the output strings in the Radac format is:

time=1516884360000;sensor=height;H1=-266.3229cm;
time=1516883700000;sensor=wob;Hm0=1.2828116cm;
time=1516884420000;sensor=height;H1=-266.33194cm;

Format01 message format

The Format01 message, formerly called the SESAM format, used by the Dutch Ministry of Infrastructure and the Environment (Rijkswaterstaat), is only defined for the heave and the 10 second mean (H parameter). It consists of 8 character lines (Line-Feed character + status character + sign character + 4 character value in cm + Carriage-Return character). For a regular message the status character is a space. If an error occurs the status character becomes a letter A. An example of the output strings in the RWS format is,

+0001
- 0004
A+9999

Format02 message format

Modifications can be made upon request. For example, the Korean Meteorological Administration (KMA) preferred a readable time format in the Korean time zone. An example of the output strings in the KMA format is:

time=2018/01/25 21:55:00;H1=-266.33362cm;
time=2018/01/25 21:44:00;Hm0=1.2197564cm;
time=2018/01/25 21:56:00;H1=-266.41037cm;

Format03 message format

The Format03 message, formerly called the FGTI format, is used by the Belgium government. Where one string is used for all required information (parameters + spectrum) per processing interval. The chosen parameters are separated by a semicolon (;) and the 51 spectrum values (czz10) are included. The 'NaN' string is replaced with a '-9999' string. An example of the output string in the FGTI format is:

time=1516884540000;sensor=wob;Hm0=1.2876906cm;H1/3=1.2812848cm;Czz10=0.0,0.008055651,
0.15104732,0.6101805,1.962359,2.8207693,0.8498019,0.96278685,0.4353935,0.38063055,0.31748414,0.21270145,
0.25863284,0.26053977,0.26529723,0.19834366,0.15177727,0.09071115,0.13891238,0.104441345,0.06950364,
0.037893698,0.030477475,0.02820262,0.026440224,0.02899744,0.03170355,0.022246486,0.017086972,0.0123491855,
0.016110778,0.024528202,0.023665352,0.02149586,0.024116969,0.03430652,0.022677578,0.02265476,0.020909032,
0.020626063,0.014051248,0.009640818,0.01388686,0.012247883,0.016294856,0.009297267,0.012917394,0.0054248176,
0.0040464,0.009096763,0.009700729cm2/Hz;

Step 6. Technical assistance

The Technical Assistance section on the 'Status' page, provides useful functionalities

The 'Diagnostics' button will cause the system to generate a file containing information about the system settings, status and performance. Please note that it can take up to 3 minutes to generate and download the diagnostics file and that it can contain up to 100 [kB] of data. It is recommended to share the diagnostics file with Radac B.V. because it can help with providing future technical support.

The 'System reboot' button, facilitates a remote system reboot. Please allow 5 minutes for the system to startup after a reboot.

The 'Reset to default' button, allows the user to remotely reset the system to its factory settings. This process is irreversible so please apply cation.

Chapter 4

Using the system

4.1 Calculated parameters

Once the system is commissioned the facilities of data presentation, reflection diagram, system info etc. can be used to monitor the proper operation of the system.

Water level and wave height information are calculated by analyzing the measurements of the WaveGuide radar. There are two analysis routines:

Wave analysis
The Standard Wave Processing Package (SWAP) is used in performing time and frequency domain analysis on the measured data to calculate wave parameters. This package is the standard processing package used by the Dutch government for wave height analysis. It also meets the standards set by The International Association of Oil & Gas Producers (OGP). A detailed description of the SWAP package is available on the Radac website (http://www.radac.nl).

The SWAP parameters are calculated every minute using 20 minute data blocks. The 20 minute observation block is chosen as a compromise between short enough to obtain "small" variance in the statistical parameters and long enough to assume it to be a stationary process. The time stamp used on SWAP parameters is the mean between the start and end time of the 20 minute data blocks.

Waterline level analysis
To analyze the ship's waterline level a number of long term averages are available. The parameters H10, H5 and H1 are calculated by averaging uncompensated measured water levels (heaveRadar) over 10 [min], 5 [min] and 1 [min] periods respectively. By origin these parameters are used to indicate the waterlevel from a static object.

Each parameter receives a time stamp central to the block of data that was used for its calculation. The spectra and parameters that can be calculated by the WaveGuide system are described in Appendix 1. Due to the large number of parameters, only a selection of the most commonly used ones is displayed on the user interface. This selection can be modified by Radac upon request.

4.2 Data logging

Each WaveGuide Onboard system is supplied with internal non-volatile memory (an SD card) for data logging. This can be used as a backup solution while sending data over the network to a primary data acquisition system. To reduce the chance of corrupting the SD-card during power failure, it is advised to use an Uninterrupted Power Supply (UPS).

The 'Data Logger' section of the configuration page in the web user interface (Fig. 4.1) gives access to the stored data. Folders as well as individual files can be downloaded using the corresponding download arrow buttons. Depending on the size of the log files, after clicking a download button it can take up to 3 minutes for the system to compress the files and start the transfer.

It is also possible to access and transfer the logged data using file transfer protocol by using ftp://"system IP address". The Login name and password for FTP access are the same as the user-name and password for modifying settings (by default both user-name and password are 'radac')

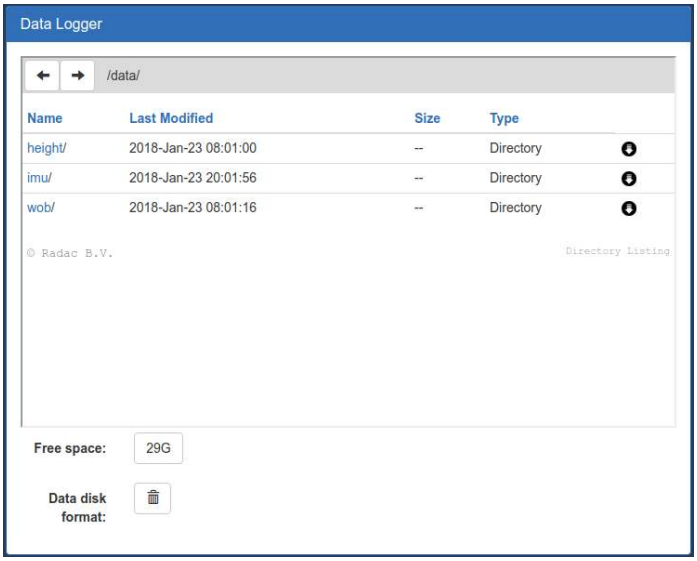


Figure 4.1: Data logger page.

The folder structure used for data logging is one directory per sub-system. In this directory, sub-directories are created that contain the raw data and parameter files (one file per day per parameter).

If the drive is full, a delete mechanism starts. This allows the system to store the most recent parameters at the expense of the oldest data.

Appendix 1: System parameters

Available parameters

Tables 1 to 6, describe all the parameters that are measured and calculated by the Wave-Guide Onboard system.

Name	Description	Unit
heaveRadar	Instantaneous uncompensated water level	cm
heaveIMU	Instantaneous radar position along vertical line	cm
heaveWOB	Instantaneous ship motion compensated water level	cm

Table 1: Raw data, heaveRadar, heaveWOB and heaveIMU at $10Hz$

Name	Description	Unit
Czz5	Energy density spectrum from 0 to 500 [mHz] in steps of 5 [mHz] (101 values)	cm^2/Hz
WTBH	Table of wave heights	cm
WTBT	Table of wave periods	s
Czz10	Energy density spectrum from 0 to 500 [mHz] in steps of 10 [mHz] (51 values)	cm^2/Hz

Table 2: Spectra and wave tables

Name	Description	Unit
Hm0	Significant wave height from M0	cm
M0	Band energy from Czz10(f) in the range f =[30-500] mHz	cm^2
M0_M	Band energy from Czz10(f) in the range f =[30-1000] mHz	cm^2
Hm0_M	Significant wave height from M0_M	cm
Tm02	Average period from M0 and M2 in the range f=[30-500] mHz	s
Tm02_M	Average period from M0 and M2 in the range f =[30-1000] mHz	s
TE0	Band energy from Czz10(f) in the range f =[500-1000] mHz	cm^2
TE1	Band energy from Czz10(f) in the range f =[200-500] mHz	cm^2
TE1_M	Band energy from Czz10(f) in the range f =[200-1000] mHz	cm^2
TE2	Band energy from Czz10(f) in the range f =[100-200] mHz	cm^2
HTE3	Wave height from TE3 (Band energy from Czz10(f) where f =[30-100] mHz)	cm
Fp	Frequency f where Czz10(f) has its maximum in the range f =[30-500] mHz	mHz
Fp_M	Frequency f where Czz10(f) has its maximum in the range f =[30-1000] mHz	mHz
AV10_H	Number of degrees of freedom in the energy density spectrum (4 * Ndlr_H)	–
HS7	Wave height from band energy from Czz5(f) in the range f =[30-142.5] mHz	cm
Tm0_1	Minus first moment period from M-1 and M0 in the range f =[30-500] mHz	s
Tm0_1_M	Minus first moment period from M-1 and M0 in the range f =[30-1000] mHz	s

Table 3: Parameters of spectral processing (over a 20 [min] data block)

Name	Description	Unit
H1/3	Average height of the highest 1/3 of the waves	cm
TH1/3	Average period of the highest 1/3 of the waves	s
H1/10	Average height of the highest 1/10 of the waves	cm
H1/50	Average height of the highest 1/50 of the waves	cm
T1/3	Average period of the longest 1/3 of the periods	s
GGH	Average height of all waves	cm
GGT	Average period of all waves	s
AG2	Number of waves	–
SPGH	Standard deviation of the wave height	cm
SPGT	Standard deviation of the wave period	s
Hmax	Height of highest wave	cm
Tmax	Period of longest wave	s
THmax	Period of highest wave	s
HCM	Crest height, maximum positive value of all data within one analysis period	cm

Table 4: Parameters from time domain processing of data collected (over a 20 [min] data block)

Name	Description	Unit
Nwt_zP	Sum of periods of waves divided by analysis period	–
Ndlr_H	Number of valid sub-series of the signal in the vertical direction	–
Ngd_zP	Percentage of data-points that do not contain error code before preprocessing	–
Nu_z	Number of valid data-points that are rejected because of 0-sigma errors	–
Nv_z	number of valid data-points that are rejected because of 4-sigma errors	–
Nd_z	number of valid data-points that are rejected because of 4-delta errors	–
Ni_z	number of interpolated or extrapolated vertical wave motion data points	–

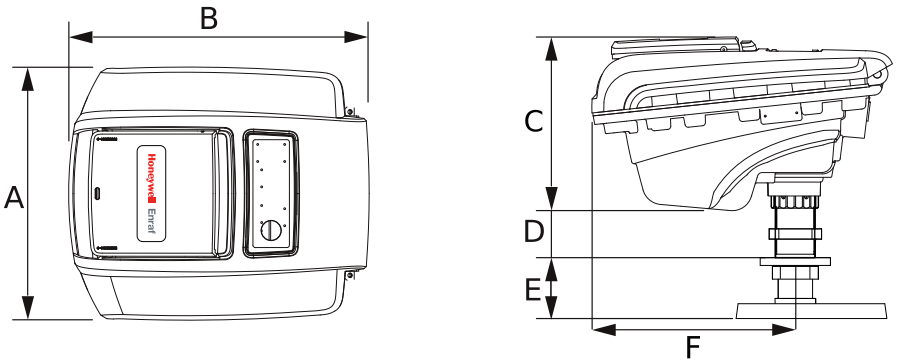
Table 5: Quality parameters (over a 20 [min] data block)

Name	Description	Unit
H	Average height over last 10 seconds	cm
H1	Average height over last 1 minute	cm
H5	Average height over last 5 minutes	cm
H10	Average height over last 10 minutes	cm

Table 6: parameters from waterline processing

Appendix 2: System specifications

Mechanical	
Weight	18.5 [kg] (incl. antenna 2.8 [kg])
Casing material	Chromatized aluminium
Electrical	
Radar frequency	9.319 – 9.831 [GHz]
Modulation	Triangular FMCW
Emission	The emitted microwave energy is far below acceptable limits for exposure of the human body. Depending on the type of antenna, a maximum radiation of 0.1 [mW] is generated.
Power requirements	24-65 [VDC] and 8 [Watt]
Power requirements	65-240 [VAC] and 8 [Watt]
Environmental conditions	
Ambient temperature	-40 to 60 [^{o}C]
Relative humidity	0 – 100 %
Ingress protection	IP67
Performance specifications	
Sampling rate	10 [Hz]
Wave heights	0 – 60 [m]
Wave periods	0 – 100 [sec
Water level accuracy	$<$ 1 [cm]
Processing period:	
Wave height	20 [min] (SWAP standard)
Water line	1, 5 and 10 [min])
processing interval:	
Wave height	Moving window, all parameters refreshed every 1 minute
Water line	Moving window, all parameters refreshed every 1 minute
Other specifications	
Processor	ARM Cortex^{TM}A9 792MHz
Connectivity	Ethernet
Memory	On board backup memory



	mm	inches
A	300	11.82
B	330	12.99
C	220	8.66
D	70	2.76
E	60	2.36
F	260	10.24

Figure 2: WaveGuide Explosion Proof dimentions.