RADAC
level, tide and wave monitoring

WaveGuide Height & Tide

User Manual

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User Manual

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WG5-HT-CP

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$\mathsf{C}\,\mathsf{E}$

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Preface

This user manual and technical documentation is intended for engineers and technicians involved in the software and hardware setup of the WaveGuide 5 Height and Tide System, Compact version (WG5-HT-CP).

Note

All connections to the instrument must be made with shielded cables with exception of the mains. The shielding must be grounded on both ends of the cable. For more information regarding wiring and cable specifications, please refer to Chapter 2.

Legal aspects

The mechanical and electrical installation shall only be carried out by trained personnel with knowledge of the local requirements and regulations for installation of electronic equipment.

The information in this installation guide is the copyright property of Radac BV, the Netehrlands.

Radac BV 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 general safety precautions for handling tools and use of electricity.

The contents, descriptions and specifications in this installation guide 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 Height & Tide is a highly accurate wave, tide and waterlevel monitoring system which is compact, robust and easy to install.

The WaveGuide Height & Tide consists of a WaveGuide radar, to be mounted above water level.

The WaveGuide radar is a low power X-band FMCW radar that measures the distance between the water surface and the radar antenna with an accuracy of < 1 [cm]. The raw reflection signal is processed and different wave and tide parameters are calculated. 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.

The WaveGuide sensors are available in two versions:

- The Explosion proof version, where the electronics are build into an explosion proof housing.

- The Compact version, where the antenna and electronics are built into a compact stainless steel housing. The antenna and electronics are the same in both versions but the stainless steel version is easier to handle due to its compact size.

This manual describes the Compact version of the WaveGuide Height & Tide. 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 specifies the WaveGuide radar positioning criteria for optimal measurement quality. Chapter 2 illustrates the correct wiring 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: System parameters for a list of measured and calculated parameters. Refer to Appendix 2: System specifications for specifications, information about certification and environmental conditions applicable to the WaveGuide height & Tide. For information on the LED blinking modes please refer to Appendix 3: LED blinking modes.

Chapter 1

Radar positioning and installation

1.1 Safety notes

The personnel installing the WaveGuide system must have basic technical skills to be able
to safely install the equipment. When the WaveGuide system is installed in a hazardous
area, the personnel must work in accordance with the (local) requirements for electrical
equipment in hazardous areas.

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 warranty and the
approval certificate.

Warning

In hazardous areas it is compulsory to:
- Use personal protection and safety gear such as hard hat, 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
  are present in the working area.
- Never start working before the work permit has been signed by all parties.

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 the equipment.

All covers of the WaveGuide radar must be closed before switching on the power.

1.2   Positioning

For obtaining the best results from a WaveGuide Height & Tide 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 can be approximated to a conical shape having a 5° [deg] half top angle as shown in Fig. 1.1). The minimum horizontal distance between a sensor and any obstacle in the beam's path should be at least 10% of the vertical distance between the sensor and the obstacle. This does not only include horizontal objects in the beam's path but also vertical structures.

- Any structure that the WaveGuide sensors are mounted to might have some influence on the waves progressing around it. Hence, it is advised to mount the sensors at a position facing the mean wave direction so that they can measure the least disturbed water surface.

- The minimum measuring distance is at 2 meter. As such, the sensor should be mounted with its reference point at least 2 meter above the highest expected waterlevel during the period in which the water surface is monitored. The reference level for the mounting height of the radars is shown in Fig. 1.2.

- A vertically mounted radar (0° [deg] tilt angle) results in optimal performance. But if necessary the WaveGuide sensor can be mounted with a maximum tilt angle of 15° [deg] (tilted to face the direction away from the structure it is mounted to).
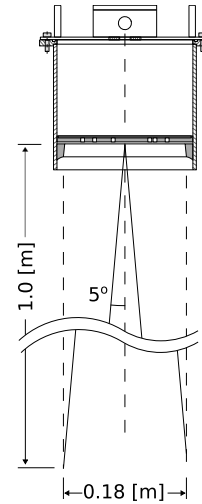

Figure 1.1: The 5° [deg] half top angle of the F08 antenna beam.
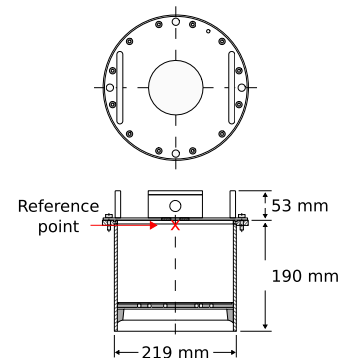

Figure 1.2: Radar dimensions and the zero reference point. Note that the reference point is located at the crossing of the central axis with the lower surface of the mounting flange.

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1.3   Installation

To facilitate the mounting of the WaveGuide radar, an optional mounting plate is available upon request (Part no. WG-MP-SS). Figure 1.3 shows a sketch of the optional mounting plate and its dimensions.

The mounting plate can be fixed to two horizontal beams (Fig. 1.4). 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).

The outside diameter of the WaveGuide radar cylinder is 219 [mm] and the total height of the system is 245[mm]. The radar cylinder has a flange (265 [mm] diameter) that contains 4 mounting holes each having a diameter of 11 [mm].

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.

The optional mounting plate has 4 threaded mounting holes (M10 thread) for mounting the WaveGuide radar to the mounting plate.

Upon request, Radac can supply an optional frame (Part no. WG-MH-SS) that allows for mounting the WaveGuide radar and mounting plate at angles 0, 5, 10, 15 and 20 [deg] away from vertical (see Fig.1.5). The radar mounting plate (Part no. WG-MP-SS) is included with this frame as well as brackets to allow mounting the frame to a handrail.
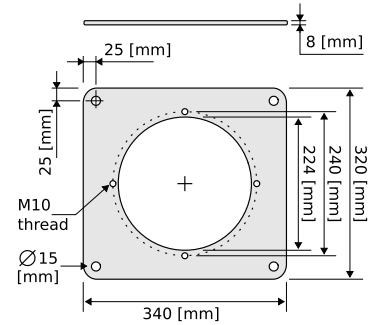
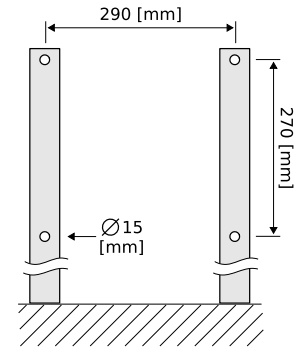Figure 1.3: Optional mounting plate for the WaveGuide radar.

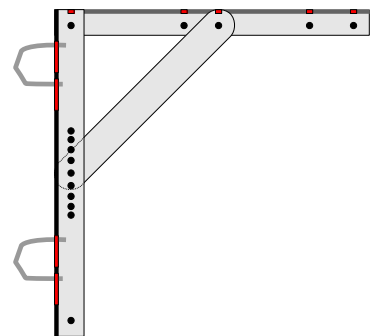Figure 1.4: Top view of the horizontal mounting beams.

Figure 1.5: Optional frame that allows mounting of the WaveGuide radar at different angles.

Chapter 2

Wiring

2.1 WaveGuide radar

A cable gland (IP68-10bar and IP69K certified) is pre-installed on the WaveGuide sensor for use on the terminal compartment as a watertight cable entry point. The supplied gland allows the installation of insulated cables from 8 to 15 [mm] in diameter.

When selecting a cable for use with a WaveGuide system, the following specifications 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, at least satisfying Category 5e Ethernet cable (Cat 5e) specifications.

- 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.

The terminal compartment contains a six pole and a two pole connector as well as a ground connection point, as shown in Fig. 2.2. The six pole connector is used to connect the Ethernet data wires. The poles labeled with Tx+, Tx-, Rx+ and Rx- relate to RJ45 pins 1,2,3 and 6. Additionally a reset function is implemented on the top two poles, which should only be temporarily connected when resetting the radar to its factory settings or setting a fixed IPV4 address.

The 2nd connector (2 pole connector) in the terminal compartment is used to supply the system with either 24-65VDC or 65-240VAC power. The poles are labeled as $+/\sim$ and $-/\sim$, yet the internal power supply operates also when the + and - poles are switched around.

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 36VDC or a 48VDC power supply.
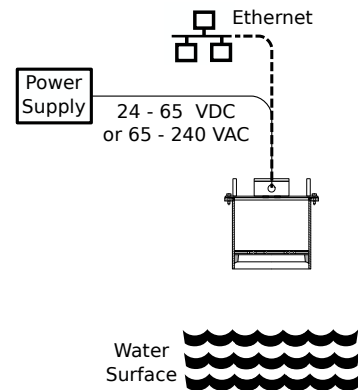

Figure 2.1: Block diagram of the Waveguide Hight & Tide system.

Figure 2.2: Terminal compartment and connections.

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The cable shielding must be connected to ground at both ends of the cable.

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

Table 2.1: Ethernet wiring instruction.

Note

Connecting the Reset poles for for 0.5 to 2 seconds during operation will cause the sensor to temporarily use the default IPV4 address 192.168.111.71 until the system is rebooted. Connecting the Reset poles for longer than 10 seconds during operation will cause the sensor to reset to default factory settings and reboot. The indicator LED will flash rapidly during this procedure. Refer to Appendix 3: LED blinking modes for a description of the LED blinking modes.

Warning

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

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!

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 twice for half a second after which it will remain off for 4 seconds. Any other blinking mode will warn you that the system is not functioning in its normal mode of operation. See Appendix 3: LED blinking modes for a description of the different LED blinking modes.

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 processing unit 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 0.5 to 2 seconds. 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**
> 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	Visualisation 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 the WaveGuide system main sections.

Step 2. Become an authorised 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 a successful authorization, the user can view and change settings. After submitting any new settings a reboot dialog will appear. To ensure proper initialization of the new settings, the WaveGuide system must be rebooted.
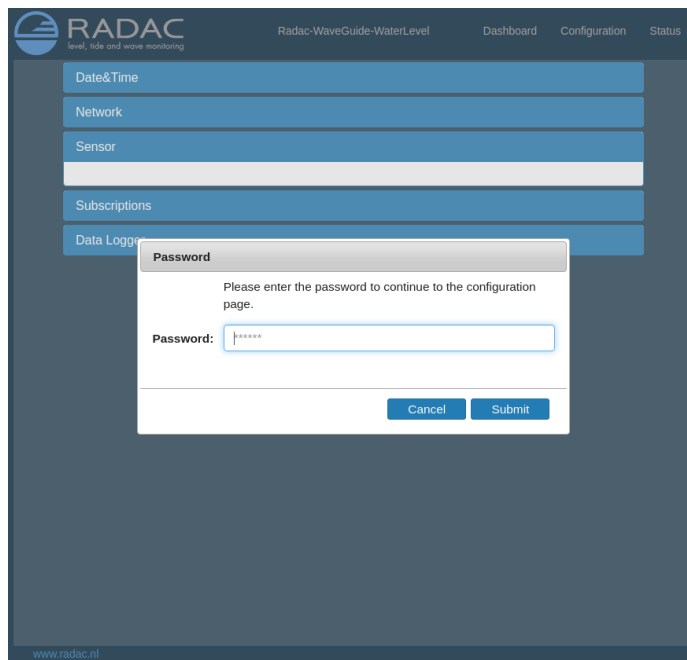

Figure 3.2: Login page.

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 an accurate timestamping 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. 3.3). Adjusting the date and time while the NTP service is running is not possible as the time will be automatically corrected back to UTC time. The date and time are kept by an on-board clock. Please be aware that such on-board clocks are not highly accurate and can drift over the years while the system is used; it is thus advised to use the NTP service.
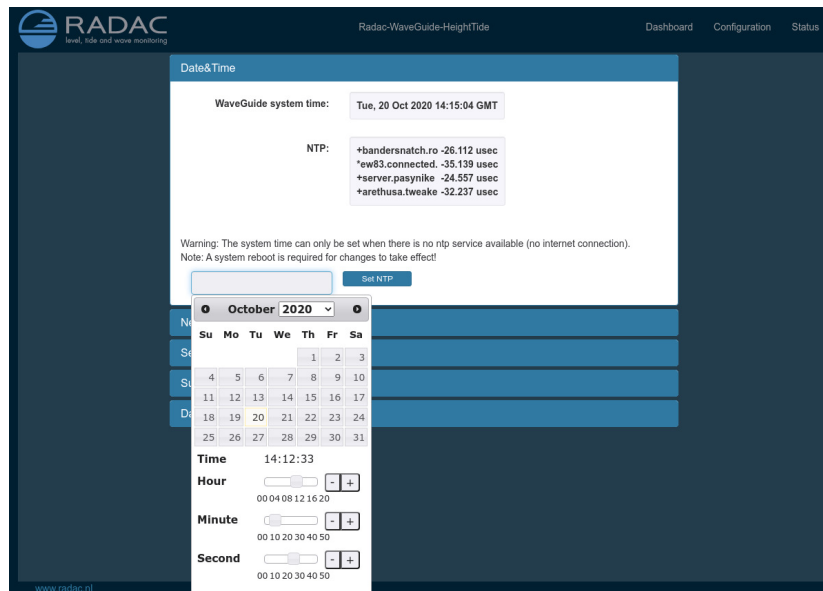

Figure 3.3: Setting the system time and date.

If the WaveGuide system is not connected to the Internet but instead connected to a local network that includes a time server, then the system can be adjusted to synchronize time and date with the local time server using the "Set NTP" button and submitting the local NTP server address.
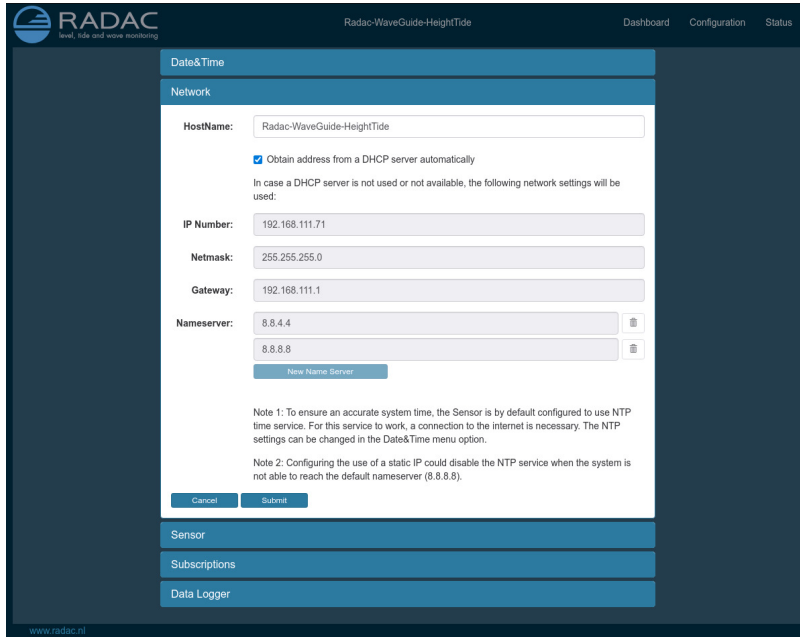
Step 3.2: Adjust network settings

Figure 3.4: Adjusting the network settings.

The network settings can be modified via the web-interface (Fig. 3.4). It is advised to use the default setting, to automatically obtain the network settings from a DHCP server, and assure from the side of the DHCP server that the system will receive the same IP-address at all times. This setting provides the easiest setup and ensures the correct settings for the local network.

Note
To ensure an accurate system time, the WaveGuide system is by default configured to use an NTP time service. For this service to work, a connection to the Internet is necessary.

Note
Configuring the use of a static IP could disable the NTP service when the system is not able to reach any nameserver. The user interface allows to manually add or remove nameserver addresses.

Step 3.3: Sensor configuration

The WaveGuide Height & Tide is designed with a high level of flexibility in mind, to apply to every possible mounting situation. The sensor menu allows the configuration of those parameters that are specific to the sensor installation. The mounting height above the reference water level, and possibly a number of other parameters, needs to be set for each specific mounting location. This can be done in the configuration table that is shown in Fig. 3.5.
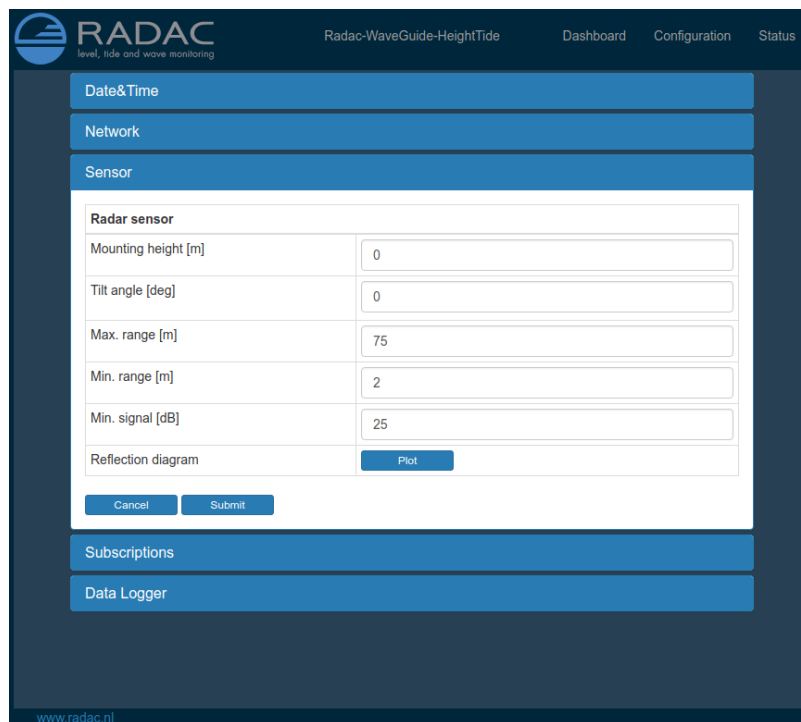
Mounting height

Figure 3.5: Setting sensor parameters (changes only take effect after the system is rebooted).

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 of each radar is the lower-side of the radar mounting flange (as shown in Fig. 1.2). 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 in [m] 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 in [m] 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 signal power that will be considered in water level measurements. This parameter is by default set to 25 [dB], and should only be

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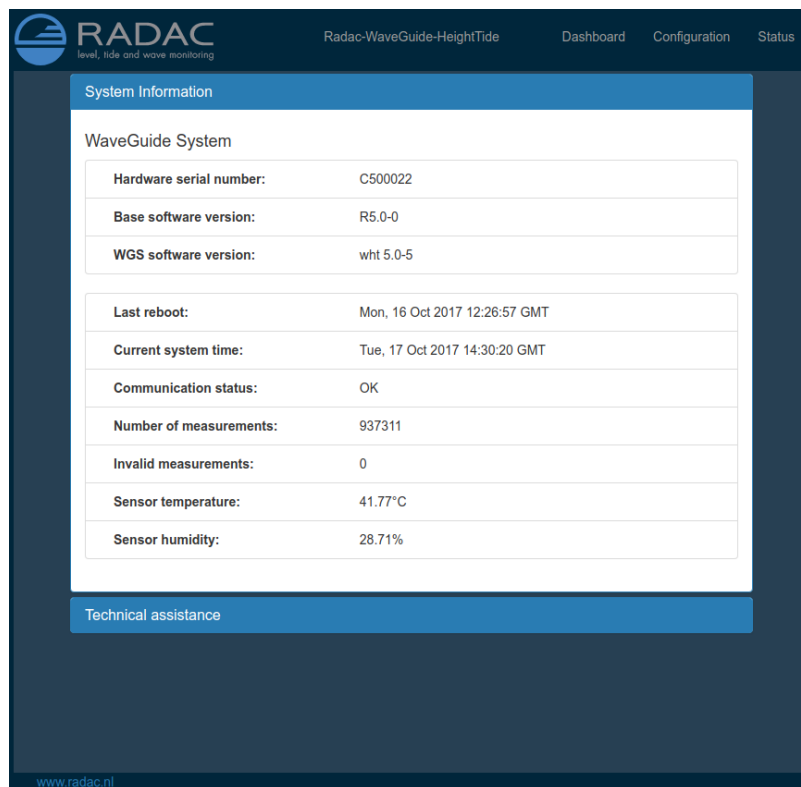
After changing the sensor parameters for the radar, rebooting the system is required for the changes to take effect. The reflection diagram of the sensor should be checked to ensure that the water level measurement is within the defined limits (More information can be found in 'Step 4.2: Check the Reflection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

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. 3.6). 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 3.6: 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 setup 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 1000 (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 for each sensor 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 25 [ms] scan, where the signal strength [dB] is plotted against the measurement distance [m]. A scan consists of one up-sweep (increasing frequency, blue curve) and one down-sweep (decreasing frequency, red curve).

Often several peaks are visible in a reflection diagram as shown in Fig. 3.7. This is caused by the multiple signal reflections between radar, water surface and any objects within the radar foot-print. The leftmost peak is generated by the so called internal reflection. The signal processing takes this phenomenon into account such that it does not have a negative effect on the measurements.
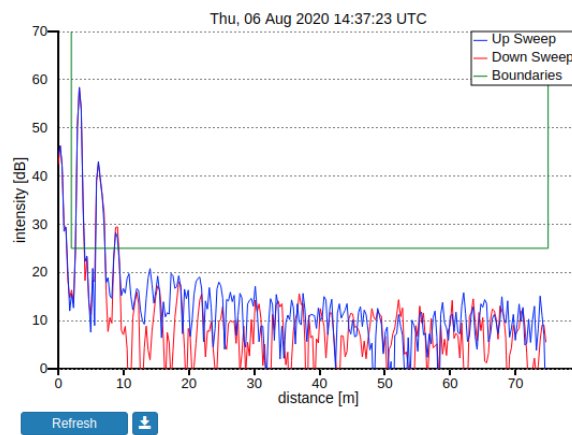
Figure 3.7: The reflection diagram gives a graphical representation of the radar signal received in a single measurement.

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

On the 'Dashboard' page, the heave parameter shows data measured during the last 1, 3 or 10 minutes. Please inspect the available heave graph to visually confirm the measured data. From the same menu all calculated parameters are available. Please take into account that it can take up to 10 minutes to gather enough raw data to calculate some of the 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), the existing subscriptions can be removed or modified and new ones can be added. Simultaneous subscriptions are possible.
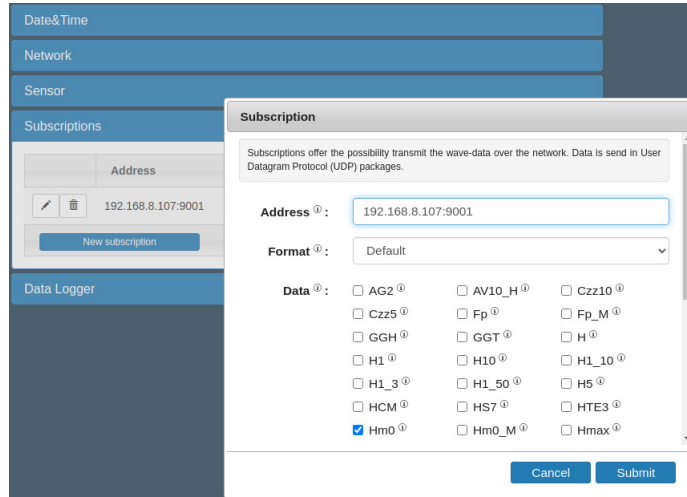

Figure 3.8: List of defined subscriptions and "New subscriptions" dialog box.

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 1st 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=1157359800206;sensor=height;H1=-319.9429cm;

time=1157359259847;sensor=height;Hm0=1.2517135cm;

time=1157359860268;sensor=height;H1=NaNcm;

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 Format02 the Korean Meteorological Administration (KMA format) 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;
```

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 block.

Tide analysis
The tide parameters H10, H5 and H1 are calculated by averaging measured data over 10 [min], 5 [min] and 1 [min] periods respectively.

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 system is supplied with internal non-volatile memory (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')
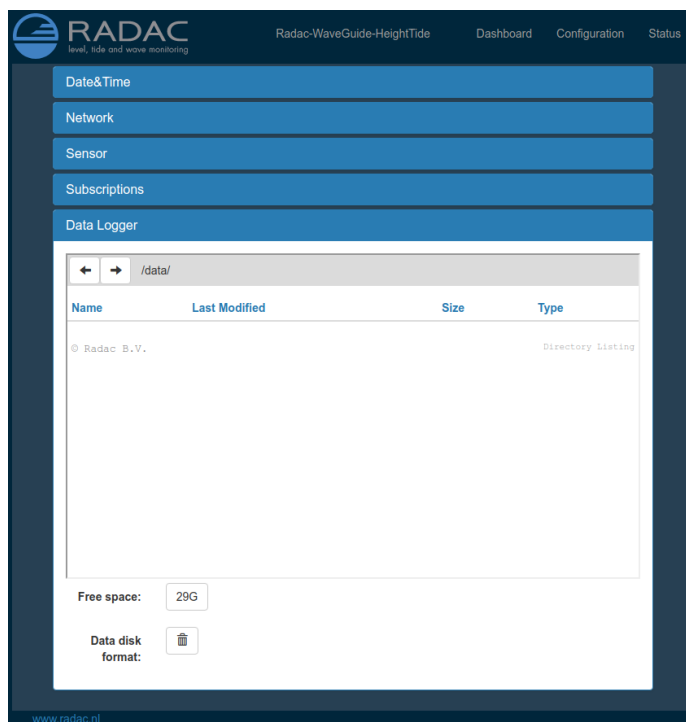

Figure 4.1: Data logger page.

In the logging directory, sub-directories are created for each parameter. Within the each parameter folder data text files (one file per day per parameter) are stored.

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

Default parameters

A selection of the raw and processed parameters is by default available for plotting, storing and export (Table 1).

Name	Description	Unit
heave	Instantaneous water level	cm
Ngd_zP	Percentage of data points that do not contain error code before pre-processing	%
Hm0	Significant wave height from M0	cm
Tm02	Average period from M0 and M2 in the range f=[30-500] mHz	s
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
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
Czz10	Energy density spectrum from 0 to 500 [mHz] in steps of 10 [mHz] (51 values)	cm^2/Hz
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 1: Default parameters

All possible parameters

Tables 2 to 7, describe all the parameters that can be measured and calculated by the WaveGuide Height & Tide system.

Adding parameters that are not available by default is possible. Added parameters will run in the background and will be available for storage and subscription, yet they will not be visible from the user interface. It is strongly recommended that the user requests the changes when the WaveGuide Height & Tide system is ordered such that all necessary tests can be performed at Radac. Post-delivery adjustments to the available parameters are possible upon request, but not recommended.

Name Description	Unit
heave Instantaneous water level	cm

Table 2: Raw data at 10 [Hz]

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

Table 3: 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 4: Spectral processing parameters

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 5: Time domain parameters.

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 6: Quality parameters.

Name	Description	Data-rate [sec]	Unit
H	Average height over last 10 seconds	10	cm
H1	Average height over last 1 minute	60	cm
H5	Average height over last 5 minutes	60	cm
H10	Average height over last 10 minutes	60	cm

Table 7: Water level parameters

Appendix 2: System specifications

WaveGuide radar

Mechanical

Dimensions	265 x 245 [mm] (diameter, height)
Weight	$\approx$ 12 [kg]
Casing material	Stainless Steel

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 65 [^oC]
Relative humidity	0 – 100 %
Ingress protection	IP67

Preformance 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)
Tide	1, 5 and 10 [min])
processing interval:	
Wave height	Moving window, all parameters refreshed every 1 minute
Tide	Moving window, all parameters refreshed every 1 minute

Other specifications

Processor	ARM Cortex™A9 792MHz
Connectivity	Ethernet
Memory	On board backup memory

Appendix 3: LED blinking modes

The WaveGuide sensor is equipped with a blue indicator LED inside the top lid. The purpose of this LED is is twofold:

- The LED functions as a status indicator when in standard operating mode. This is the status mode of the LED.

- The LED provides visual assistance when the 2 contacts are connected. This is the settings mode of the LED.

Settings mode

When a connection is made between the 2 contacts labeled 'reset' the LED will start blinking rapidly at 10 Hz. Depending on when the connection is broken again, the following will happen:

- If the connection lasts between 0.5 and 2 seconds, the ip address is set to the default of 192.168.111.71.

- If the connection lasts between 2 and 10 seconds, nothing happens. During this phase the LED stops blinking. After 10 seconds the LED starts blinking again.

- If the connection lasts more than 10 seconds, the system will be reset to the factory settings, ip address NOT included. However, the system will also receive the default ip address (192.168.111.71) as its second ip address.

After the settings mode is exited the LED will switch to the status mode again.

Status mode

During operational mode the LED indicates the status of the device by blinking a number of times. The blinking signal consists of a certain number of flashes at 0.5 seconds interval followed by a downtime of 4 seconds. The signal is then repeated. The status of the system determines the number of flashes within the signal.

Table 8 describes the LED's indicator functions.

Indicator pattern		Definition	Remark
Off		No power connected.	–
Solid on		Power is connected and the system is starting.	Wait for 2 minutes, after which the indicator should change its behavior.
Blink 1 time		The system is up and running, but no network is detected.	Check the network cable connections.
Blink 2 times		The system is working normally.	This is the default mode.
Blink 3 times		The ip address was set to the default 192.168.111.71.	Check chapter 3 on how to connect to the sensor.
Blink 3 times		The system was reverted to the factory defaults. Also the default ip address 192.168.111.71 was set.	On release of the reset contact the system will be restarted.

Table 8: Blinking modes