SOTIRIA

OPERATION MANUAL

v.260220

1 CONTENTS

2 MANUFACTURER INSTRUCTIONS AND SAFETY NOTES

- The device is intended for **underwater operation.**
- After each deployment, **clean** the **device** and its **cable** with **fresh water** and **mild dish soap.** During **long deployments**, it is recommended to retrieve the device and **repeat the cleaning maintenance procedure at least once a month.**
- The device must be stored in a **dry environment at room temperature**, away from **children** and **flammable materials.**
- **Do not place** the device near **strong magnetic fields.**
- For optimal operation during measurements, **do not place** the device **near ferromagnetic objects** (e.g. steel frames, anchor chains, etc.).
- The **recommended submersion depth** is **up to 50 m. Do not submerge** the device in **depths greater than 300 m or in corrosive liquids.**
- **Do not expose the device to fire** or generally to temperatures higher than the recommended.
- **Do not open** the device or **modify** its hardware or software.
- **Do not impact, puncture, or heat** the device.
- **Do not bend, press or scratch the hydrophone.**
- The **hydrophone** includes an **exposed wire** that is connected to the **device's Ground. Do not apply any voltage to this wire.**
- For the best **hydrophone sensitivity, use it when it is fully submerged.**
- **Do not connect** the device wires to **voltages different** from those specified in this manual.
- **Do not power** the device at voltages outside the range of **7-30 V_{DC}.**
- **Do not extend** the device's cable or use cable with **different specifications.**
- **Do not pull the device from its cable** and avoid **bending** or **twisting** it.
- During operation, it is recommended to keep the device **as stationary as possible** to avoid motion artifacts caused by the Earth's magnetic field. The use of **a mounting frame** made of **non-ferromagnetic** materials is recommended.
- To **prevent galvanic corrosion** during long deployments, **avoid direct contact** of the device's aluminum enclosure with **other metals.**
- **CAUTION**: The device includes a **pressure relief valve.** Make sure to **tighten it clockwise** by hand before deployment. Otherwise, the device will be **flooded** and **permanently destroyed.**
- The device includes a **resettable (PPTC) fuse.** If a short circuit occurs, after you have ensured that the fault is resolved, wait for **up to 10 minutes** before retrying to operate the device.

3 DEVICE DESCRIPTION

The device includes a magnetic sensor, an acoustic sensor, an Inertial Measurement Unit (IMU) and an environmental (temperature/humidity/pressure sensor), as well as the necessary electronic components for edge processing of the related data. It can be powered by a 7-30 V_{DC}, ≥1 A power supply. It communicates via RS-485 using the Modbus RTU registers described in the following chapters. Alternatively, a power and communication device (sold separately) can be used to retrieve the data and send it via Wi-Fi, 4G, Ethernet, or USB.

The main features of each sensor are described below.

3.1 Magnetic sensor

- 3-axis open-loop fluxgate sensor, for detecting slow (DC - 10 Hz) magnetic field variations.
- Measures magnetic field in each axis (X, Y, Z) in nT (axes orientations are shown in Figure 10).
- Outputs the results, as well as the Total magnetic field magnitude, i.e. $\sqrt{X^2 + Y^2 + Z^2}$ and the variation of the magnetic field measurements.
- The variation output is generally the most useful result, as it highlights sudden magnetic field anomalies and is not affected by slow geomagnetic field changes or long-term magnetic drift.

3.2 Acoustic sensor

- PZT-based hydrophone.
- Captures and processes audio data.
- Outputs the top 10 dominant frequencies detected by FFT analysis, along with their Sound Pressure Levels (SPL) in dB re 1 μPa.

3.3 IMU (Inertial Measurement Unit)

- Uses a combination of accelerometer/gyroscope/magnetometer measurements.
- Captures device’s orientation in 3D space.
- Outputs yaw, pitch and roll in degrees.

3.4 Environmental sensor

- Uses a temperature sensor, a humidity sensor and a pressure sensor.
- Measures the conditions inside the device’s enclosure for health monitoring.
- Outputs temperature in °C, humidity in %RH and pressure in hPa.

4 OPERATION

4.1 Before deployment

Table 1. Wire connections.

Wire Color	Wire Function
SILVER	GND (Cable shielding)
BLACK	GND
RED	V+ (7-30 VDC)
WHITE	RS485 A+
GREEN	RS485 B-

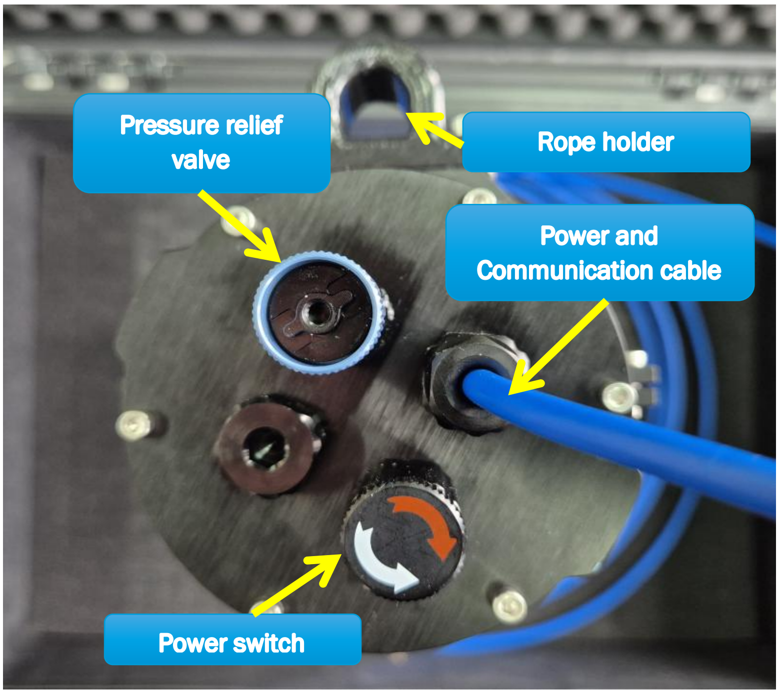

Figure 1. Device's Front Panel.

1. **Secure** the device to a **rigid non-ferromagnetic mounting frame.** Be careful **not to mechanically stress the device's cable.** In case of using the device **without a mounting frame**, secure a rope through **both the rope holder** (shown in Figure 1) and the included **cable tether** that is already tied to the cable.

2. **Connect** the **A** and **B RS485 wires** to the A and B terminals of the RS485 communication device, as shown in Table 1.

3. **Connect** the **+V** and the **two GND wires** to a **DC power supply** in the range of **7-30 V_{DC}, ≥1 A**, as shown in Table 1. A **12 V_{DC} power supply with minimal noise** is recommended.

   WARNING: Although the device includes a reverse polarity protection circuit, be careful **not to connect the power terminals in reverse!**

4. **CAUTION: Check** that the **pressure relief valve** (shown in Figure 1) is placed on the device and is fully **tightened.** If not, tighten it by rotating it clockwise by hand. Otherwise, the device will be flooded and permanently damaged!

5. **Power on the power supply** and **verify** that the **voltage output is as indicated, i.e. 7-30 V_{DC}.**

6. **Power on the device** by **rotating the ON/OFF circular Power switch** (shown in Figure 1) clockwise by hand.

7. **Verify** that the **data stream is consistent** at your terminal device.

8. **Deploy** the device to a **depth of up to 50 m.** Ensure that the **data keep updating** and that the **IMU (yaw, pitch, roll) values** indicate **no device motion** (which would affect the magnetic measurements). Otherwise, **reposition** the device and/or use a more rigid mounting frame.

4.2 Upon retrieval

1. **Turn the ON/OFF circular switch counterclockwise** by hand to power off the device.

2. **Disconnect** the device **wires** from the **power supply** and the **RS485 communication device.**

3. **Clean** the **device** and its **cable** with **fresh water** and **mild dish soap.**

4.3 Transportation and Storage

1. **CAUTION:** When transported **by air**, both the **device's pressure relief valve** and the **case's pressure relief valve** must be **loosened** to prevent pressure-related issues.

2. During transportation, **avoid any shocks, impacts or intense vibrations.**

3. **Store** the device in a **dry environment at room temperature**, away from **flammable materials** and **strong magnetic fields.**

5 RS-485 COMMUNICATION

5.1 Connecting to the device

The device uses the **Modbus RTU** communication protocol via the **RS-485** interface.

To communicate with the device, use the following settings:

Setting	Value
Baud rate	115200 bps
Data bits	8
Parity	None
Stop bits	1

5.2 Reading Acoustic Sensor Data (Slave ID = 1)

Modbus Slave ID	1
Modbus Function	0x03 (Read Holding Registers)
Starting Address	0
Ending Address	39

Registers	Content	Unit	Type
0-1	Frequency #1	Hz	Float (IEEE 754)
2-3	SPL #1	dB re 1μPa	Float (IEEE 754)
4-5	Frequency #2	Hz	Float (IEEE 754)
6-7	SPL #2	dB re 1μPa	Float (IEEE 754)
8-9	Frequency #3	Hz	Float (IEEE 754)
10-11	SPL #3	dB re 1μPa	Float (IEEE 754)
12-13	Frequency #4	Hz	Float (IEEE 754)
14-15	SPL #4	dB re 1μPa	Float (IEEE 754)
16-17	Frequency #5	Hz	Float (IEEE 754)
18-19	SPL #5	dB re 1μPa	Float (IEEE 754)
20-21	Frequency #6	Hz	Float (IEEE 754)
22-23	SPL #6	dB re 1μPa	Float (IEEE 754)
24-25	Frequency #7	Hz	Float (IEEE 754)
26-27	SPL #7	dB re 1μPa	Float (IEEE 754)

28-29	Frequency #8	Hz	Float (IEEE 754)
30-31	SPL #8	dB re 1μPa	Float (IEEE 754)
32-33	Frequency #9	Hz	Float (IEEE 754)
34-35	SPL #9	dB re 1μPa	Float (IEEE 754)
36-37	Frequency #10	Hz	Float (IEEE 754)
38-39	SPL #10	dB re 1μPa	Float (IEEE 754)

5.3 Reading Magnetic Sensor Data (Slave ID = 2)

Modbus Slave ID	2
Modbus Function	0x03 (Read Holding Registers)
Starting Address	0
Ending Address	9

Registers	Content	Unit	Type
0–1	X-axis magnetic field	nT	Float (IEEE 754)
2–3	Y-axis magnetic field	nT	Float (IEEE 754)
4–5	Z-axis magnetic field	nT	Float (IEEE 754)
6–7	Total magnitude	nT	Float (IEEE 754)
8-9	Variation	nT	Float (IEEE 754)

5.4 Reading Environmental Sensor Data (Slave ID = 2)

Modbus Slave ID	2
Modbus Function	0x03 (Read Holding Registers)
Starting Address	11
Ending Address	16

Registers	Content	Unit	Type
11–12	Temperature	°C	Float (IEEE 754)
13–14	Humidity	%RH	Float (IEEE 754)
15–16	Pressure	hPa	Float (IEEE 754)

5.5 Reading IMU Data (Slave ID = 2)

Modbus Slave ID	2
Modbus Function	0x03 (Read Holding Registers)
Starting Address	17
Ending Address	22

Registers	Content	Unit	Type
17–18	Yaw	degrees	Float (IEEE 754)
19–20	Pitch	degrees	Float (IEEE 754)
21–22	Roll	degrees	Float (IEEE 754)

5.6 Data Decoding

All sensor data are encoded as **32-bit IEEE 754 floating-point numbers**, split across **two consecutive 16-bit holding registers.**

Register layout:

- **First** register (lower address): bits **0–15** of the 32-bit float (**low word**)
- **Second** register (higher address): bits **16–31** of the 32-bit float (**high word**)

Example

To read registers 0-1 of Slave ID = 1 (Acoustic Sensor), that have the following values:

Register 0 (low): `0x0000`   Register 1 (high): `0x447A`

```
uint32 = (0x447A << 16) | 0x0000 = 0x447A0000
```

Which, based on IEEE 754, corresponds to 1000.0 (Hz).

Python example:

```
import struct
raw = (0x447A << 16) | 0x0000
value = struct.unpack('f', struct.pack('I', raw))[0]
```

Python full example code:

```
# pip install pymodbus pyserial

import struct
import time
import sys
from pymodbus.client import ModbusSerialClient
```

```python
CURSOR_HOME = "\033[H"
CLEAR_SCREEN = "\033[2J"
CLEAR_TO_END = "\033[J"

COM_PORT = "COM16" # Change to your port (e.g. /dev/ttyUSB0 on Linux)
BAUD_RATE = 115200
POLL_INTERVAL = 0.2 # seconds

def decode_float(low, high):
    raw = (high << 16) | low
    return struct.unpack('f', struct.pack('I', raw))[0]

def read_acoustic(client, lines):
    try:
        result = client.read_holding_registers(50, count=40, device_id=1)
        if result.isError():
            lines.append(f"  Acoustic read error ({result})")
            return
        regs = result.registers
        if len(regs) < 40:
            lines.append(f"  Acoustic partial response ({len(regs)}/40 registers)")
            return
    except Exception as e:
        lines.append(f"  Acoustic offline ({e})")
        return

    lines.append("  Acoustic — Top Frequencies:")
    for i in range(10):
        base = i * 4
        freq = decode_float(regs[base], regs[base + 1])
        spl = decode_float(regs[base + 2], regs[base + 3])
        lines.append(f"    #{i+1:2d}  {freq:10.2f} Hz  {spl:8.2f} dB")

def read_magnetic(client, lines):
    try:
        result = client.read_holding_registers(0, count=37, device_id=2)
        if result.isError():
            lines.append(f"  Magnetic read error ({result})")
            return
        regs = result.registers
        if len(regs) < 37:
            lines.append(f"  Magnetic partial response ({len(regs)}/37 registers)")
            return
    except Exception as e:
        lines.append(f"  Magnetic offline ({e})")
        return
```

```
    lines.append("  Magnetic Field:")
    lines.append(f"    X: {decode_float(regs[0], regs[1]):.2f} nT")
    lines.append(f"    Y: {decode_float(regs[2], regs[3]):.2f} nT")
    lines.append(f"    Z: {decode_float(regs[4], regs[5]):.2f} nT")
    lines.append(f"    Total: {decode_float(regs[6], regs[7]):.2f} nT")
    lines.append(f"    Deviation: {decode_float(regs[8], regs[9]):.2f}")

    lines.append("  Environment:")
    lines.append(f"    Temperature: {decode_float(regs[11], regs[12]):.2f} °C")
    lines.append(f"    Humidity: {decode_float(regs[13], regs[14]):.2f} %RH")
    lines.append(f"    Pressure: {decode_float(regs[15], regs[16]):.2f} hPa")

    lines.append("  Orientation:")
    lines.append(f"    Yaw: {decode_float(regs[17], regs[18]):.2f}°")
    lines.append(f"    Pitch: {decode_float(regs[19], regs[20]):.2f}°")
    lines.append(f"    Roll: {decode_float(regs[21], regs[22]):.2f}°")

def main():
    client = ModbusSerialClient(
        port=COM_PORT, baudrate=BAUD_RATE,
        bytesize=8, parity='N', stopbits=1, timeout=1,
    )
    if not client.connect():
        print("Could not connect. Check COM port.")
        sys.exit(1)

    sys.stdout.write(CLEAR_SCREEN)
    print(f"Reading from {COM_PORT}. Press Ctrl+C to stop.\n")
    try:
        while True:
            lines = []
            now = time.time()
            ms = int((now % 1) * 1000)
            lines.append(time.strftime("[%H:%M:%S", time.localtime(now)) + f".{ms:03d}]")
            read_acoustic(client, lines)
            read_magnetic(client, lines)
            sys.stdout.write(CURSOR_HOME + "\n".join(lines) + "\n" + CLEAR_TO_END)
            sys.stdout.flush()
            time.sleep(POLL_INTERVAL)
    except KeyboardInterrupt:
        print("\nStopped.")
    finally:
        client.close()

if __name__ == "__main__":
    main()
```

6 ACQUIRED DATA EXAMPLES

6.1 Magnetic detection

In the following figures, the magnetic data retrieved during the detection of a ship are depicted. The magnetic field variation is easily observed at all 3 magnetometer axes, as well as at the total magnetic field plot. To distinguish it even better, the device uses a model to calculate the magnetic field deviation of recent readings from a rolling average baseline.

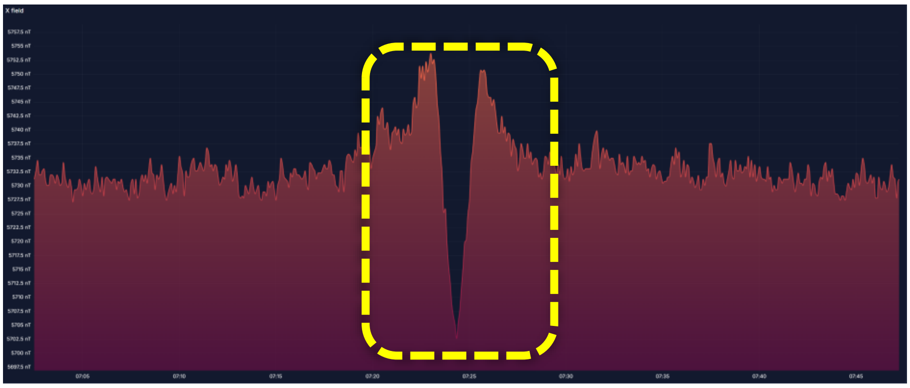

Figure 2. Example of the magnetic field variation at the X axis during a ship detection.

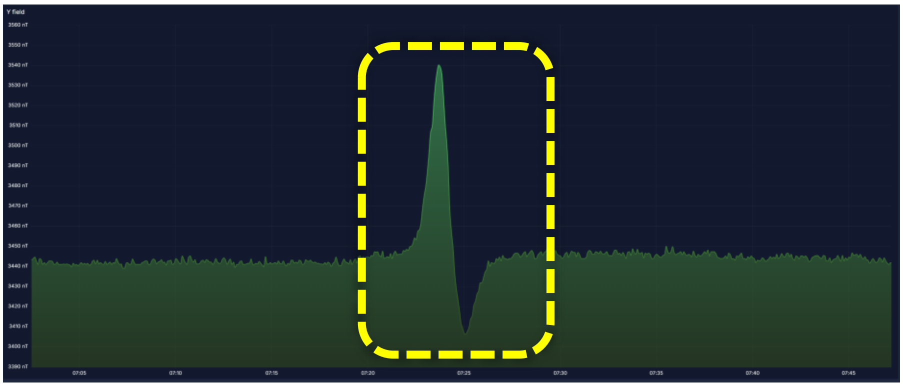

Figure 3. Example of the magnetic field variation at the Y axis during a ship detection.

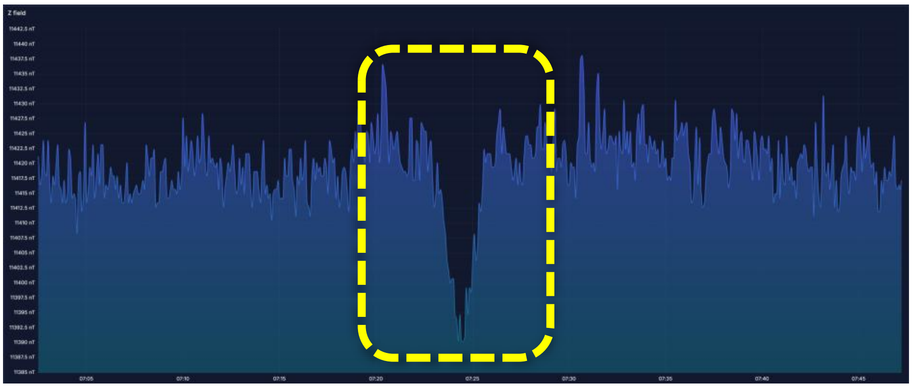

Figure 4. Example of the magnetic field variation at the Z axis during a ship detection.

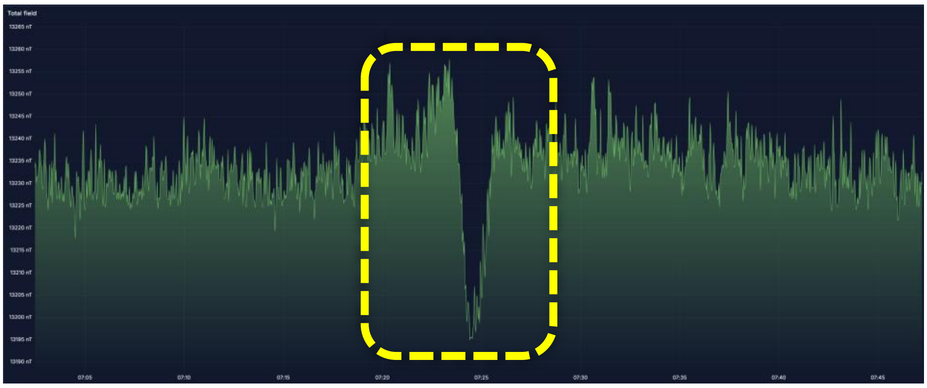

Figure 5. Example of the total magnetic field variation during a ship detection.

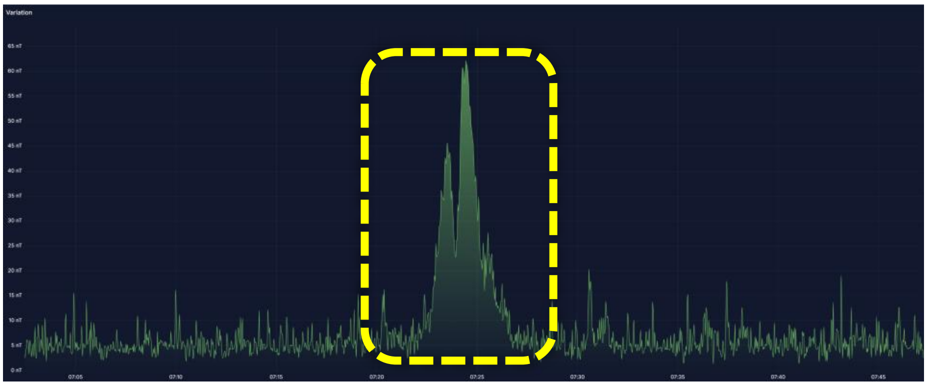

Figure 6. Example of the total magnetic field variation during a ship detection.

6.2 Acoustic detection

In the following figures, the acoustic data captured during the detection of different ships are presented as spectrograms that include the 10 most dominant frequencies, calculated by the device implementing a Fast Fourier Transform (FFT).

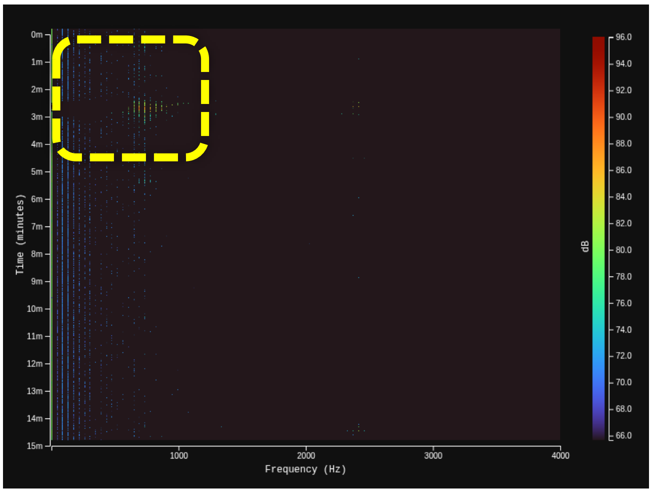

Figure 7. Example of ship detection by the acoustic sensor.

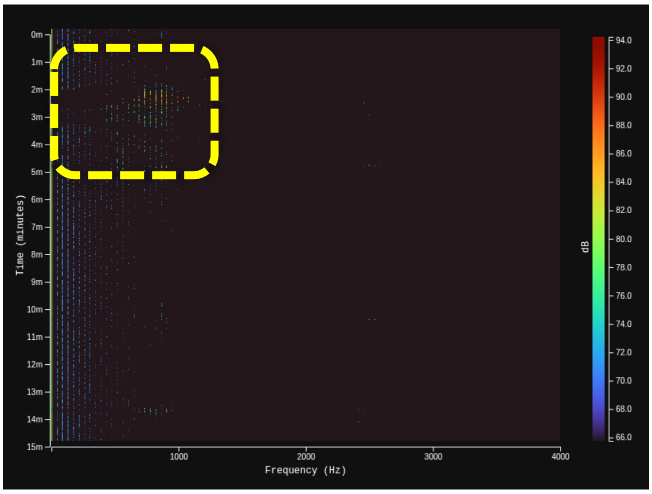

Figure 8. Example of ship detection by the acoustic sensor.

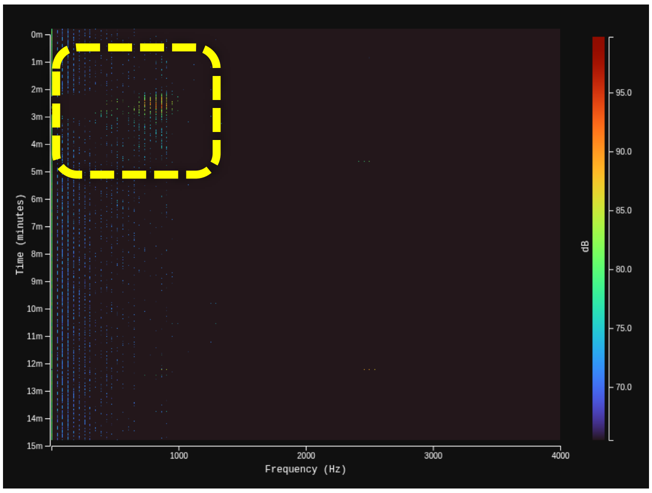

Figure 9. Example of ship detection by the acoustic sensor.

7 DEVICE DIMENSIONS

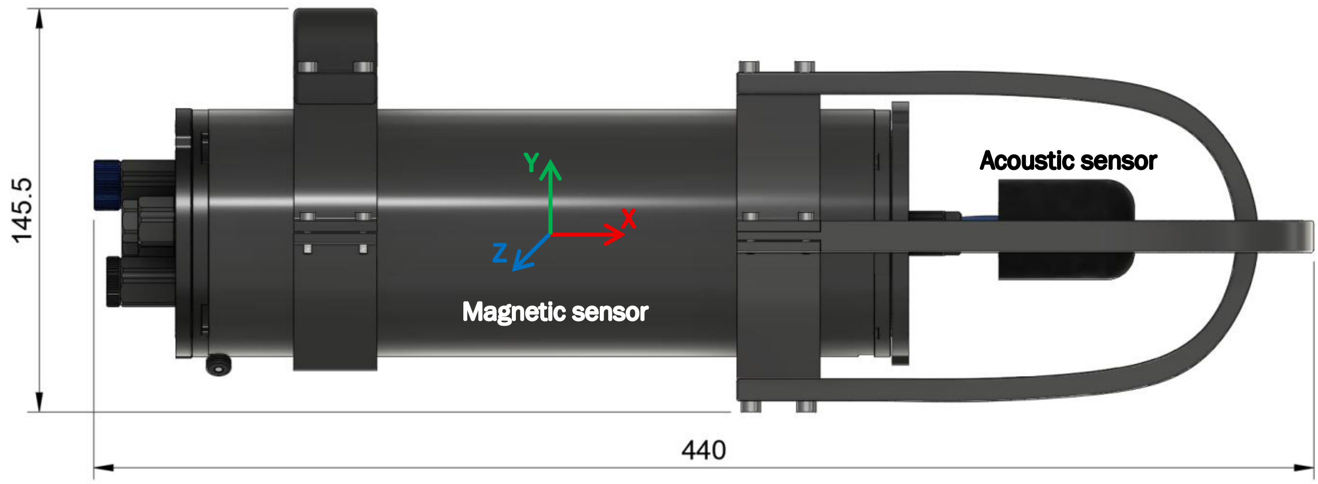

Figure 10. Device's Side view and Magnetometer orientation.

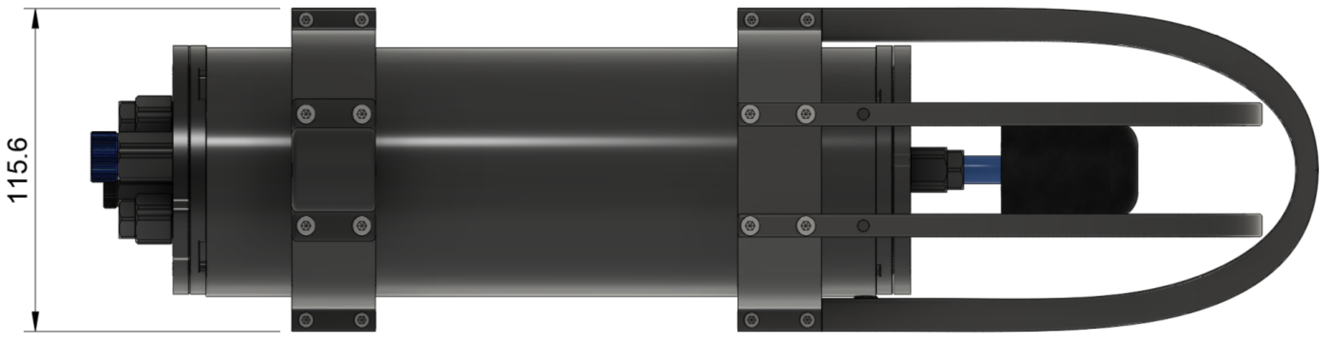

Figure 11. Device's Top view.

8 TROUBLESHOOTING

Symptom	Possible cause	Solution
No response from both nodes	Device not powered	Check power supply and its wiring and ensure the device's power switch is fully turned clockwise
No response from both nodes	A/B wires swapped	Swap A and B connections on the adapter
No response from both nodes	Wrong COM port	Check Device Manager (Windows) or `ls /dev/ttyUSB*` (Linux)
No response from both nodes	Baud rate mismatch	Ensure baud rate is set to 115200
No response from both nodes	GND not connected	Ensure both adapter and device share the same GND
No response from one node	Wrong slave ID	Acoustic = 1, Magnetic/IMU/Environmental = 2
Intermittent timeouts	Electrical noise	Relocate the cable away from sources of electrical noise
Data lag or corrupted	Too frequent or too slow polling	Try a polling frequency of 1 Hz
Data reads as 0 or NaN	Sensor hardware fault	Reset the device by turning its power switch OFF and then ON again
Magnetic measurements saturated/not changing	Strong magnetic field nearby	Relocate the device and/or check for nearby magnets or ferromagnetic objects
Magnetic measurements fluctuate a lot	Motion artifacts	Stabilize the device to reduce its movement
Acoustic measurements not changing	Hydrophone is obstructed or not submerged	Place the device in a way that the hydrophone is not obstructed by other objects and is fully submerged underwater

9 TECHNICAL SPECIFICATIONS

Power	
Supply voltage	7-30 V_{DC}
Supply current	~200 mA at 12 V_{DC}
Power consumption	2.5 W
Communication	
Output	Digital
Interface	RS485
Protocol	Modbus RTU
Baud rate	115200 bps
Typical polling rate	1-10 Hz
Enclosure	
Material	Anodized aluminum
Total diameter	145.5 mm
Total length	440 mm
Operating Temperature	-10°C to +80 °C
Recommended operating depth	50 m
Maximum operating depth	300 m
Weight (in air)	1900 g
Cable	
Length	3 m
Outer diameter	5.3 mm
Weight (in air)	~138 g
Structure	2 shielded twisted pairs
Wire size	22 AWG
Jacket material	LSZH (Low Smoke Zero Halogen)
Operating temperature	-20°C to 80°C
Magnetic sensor	
Noise level	<15 $pT/\sqrt{Hz}$
Sensitivity	97 mV/μT
Absolute range	65 μT
Frequency response	DC to 10 Hz
Acoustic sensor	
Sensitivity	-190 dB re 1 V/μPa
Bandwidth	10 Hz to 50 kHz

Sensing element	PZT (Lead Zirconate Titanate)
Encapsulation	Polyurethane resin
Inertial Measurement Unit	
Pitch accuracy	~1°
Roll accuracy	~1°
Yaw accuracy	~2-5°
Temperature sensor	
Range	–40 °C to +85 °C
Accuracy	±1 °C
Resolution	~0.01 °C
Humidity sensor	
Range	0–100% RH
Accuracy	±3% RH
Resolution	~0.008% RH
Pressure sensor	
Range	300 hPa to 1100 hPa
Accuracy	±1 hPa
Resolution	~0.18 Pa

10 ELECTROMAGNETIC COMPATIBILITY (EMC) NOTES

The device is intended for underwater use only and does not use any active means of Radiofrequency (RF) emissions. Under the exposure to 50Hz magnetic fields the free space measurements of the magnetic field may deviate up to 5%, while under the exposure to 150MHz-300MHz RF fields the free space measurements of the magnetic field may deviate up to 100%.

11 EXPORT CONTROL NOTE

The device specifications do not meet the criteria to be considered as dual-use items. As a result, it does not need an export license.

12 CE COMPLIANCE

CE

This product complies with the essential requirements of applicable European Union directives and regulations. Conformity has been assessed in accordance with the relevant harmonized standards. The EU Declaration of Conformity is available on request from the manufacturer or authorized representative.

13 ROHS COMPLIANCE

RoHS

This product complies with the requirements of the Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU and its amendments, including Directive (EU) 2015/863. The product does not contain restricted substances above the maximum concentration values specified in the Directive, with the exception of applications covered by valid exemptions under Annex III. The integrated piezoelectric (PZT) hydrophone contains lead in a ceramic material and is compliant under the applicable RoHS exemption for lead in piezoelectric devices.

14 DISPOSAL

This device contains electronic components and materials that should not be disposed of with household waste. For information about collection and recycling options, contact your local waste management authority or authorized distributor.

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