

# THE USE OF UNDERWATER COMMUNICATION MODEM IN STAND – ALONE MEASURING MODULE

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*Modem for underwater communication is two-way communication hydroacoustic system. Modem uses frequency modulation FSK data in the aquatic environment. The paper describes the different blocks of the modem, which include system transmitter, receiver and processor chip. Describes the basic parameters of the modem, such as a modem coverage of 2000m, a carrier frequency of 35kHz. It also presents the results of laboratory tests carried out in an anechoic pool measuring and test results carried out in the real world for two bodies, a closed basin yacht marina, where there were reflections from the walls of the pool and the harbor channel, where the level of the reflected signal was negligible. In an environment where there were strong-multipath reflections, it was necessary to shorten the duration of the bit and increase the time between bits to get the correct data transmission. Describes the initialization procedure calls and commands sent between the individual above water, and stand-alone measuring module.*

## INTRODUCTION

Autonomous measurement module, a device for measuring the parameters of the marine environment using multiple sensors. The module is placed on the bottom of the sea and can record changes in environmental parameters for 30 days, without the involvement of a supervisor. After 30 days, the measuring unit should be drawn to the surface, is used for the lifting device, which undoes the anchor. Anchor can be undone in two ways: when the time expires and the command sent using underwater communications. Detaching the anchor when the time expires is an emergency option. At the time of the module departure on the sea surface, may prevail adverse weather conditions which make it impossible to take the module. In addition, it may be that the module will exit the flowing unit. Communication underwater give controlled ascent module on-demand provider. In addition to the time control module ascent, underwater communication makes it possible to control the state of the battery, or the

amount of free disk space, and the ability to manage the most important settings of the measuring module.

1. GENERAL CHARACTERISTICS OF UNDERWATER COMMUNICATIONS SYSTEM

The two-way hydroacoustic underwater communication, whose functional diagram is shown in Fig.1, is used to communicate with the operator PC / Laptop with a stand-alone measuring module located in the depths of the sea or on the seabed. The basic element of the system are modems, through which it is possible to digital underwater communication.

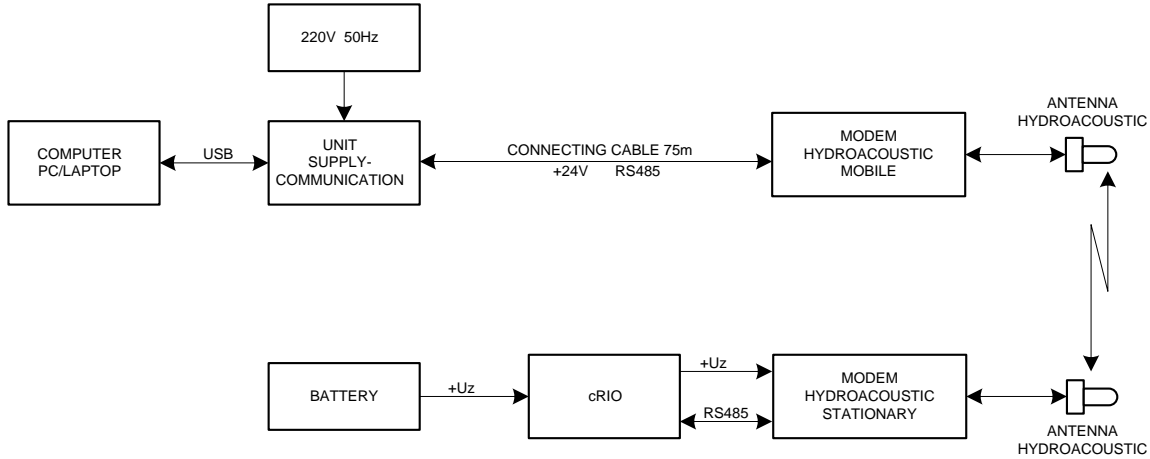


Fig.1. Functional diagram of the system of two-way hydroacoustic underwater communication.

One of the modems - hydroacoustic modem mobile, is placed special pressure housing (Fig.2) and is controlled from a PC / Laptop via the device power supply and communication (communication device) and connecting cable (75m).

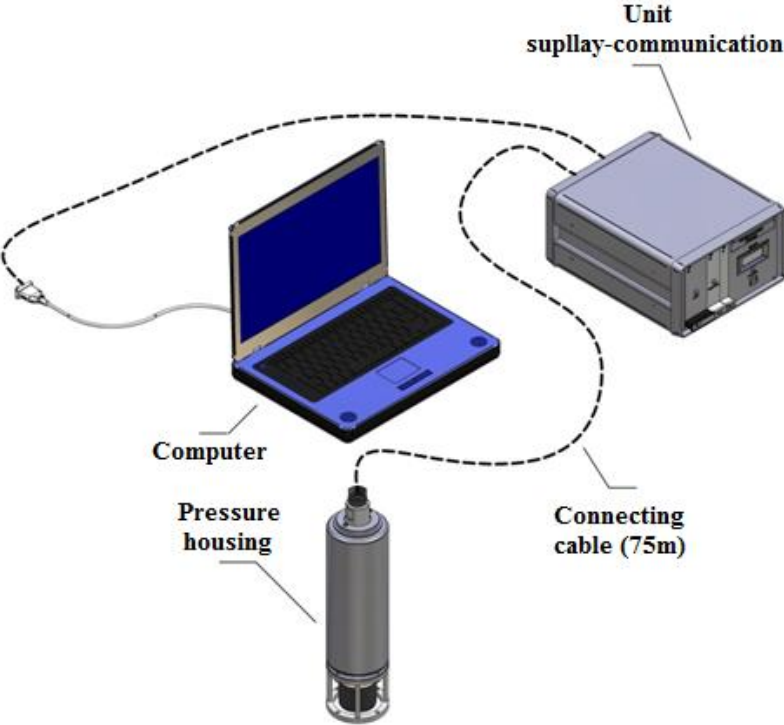


Fig.2. Mobile set the modem.

The second modem - stationary hydroacoustic modem, is placed in the measuring device and controlled from a computer that is one of the components of the device. The electronic system is similar to the two modems. However, there is a different way to controlling their power. Mobile hydroacoustic modem is powered directly from the network 220V 50Hz. However, the stationary hydroacoustic modem is powered with battery Li-Pol voltage of 14.8V.

### 2. THE BASIC PARAMETERS

Hydroacoustic modem has the following parameters:

- 250 $\mu$ Vpp receiver sensitivity;
- log.0 frequency 32kHz;
- log.1 frequency 34kHz;
- frequency of 36kHz signal the start of cooperation;
- 3ms pulse duration;
- the duration of one bit of 15ms;
- the duration of one byte 120ms;
- output power of the transmitted signal 100W or 200W;
- average current consumption of about 165mA;
- supply voltage 9V to 36V;
- sensing distance max. 2000m

### 3. CHARACTERISTICS OF UNIT SUPPLY – COMMUNICATION

The primary purpose of the device is the unit supply – communications (Fig.3) power and ensure communications with a portable modem. Additionally, the pointer is a digital modem displays the immersion depth of the sea surface.

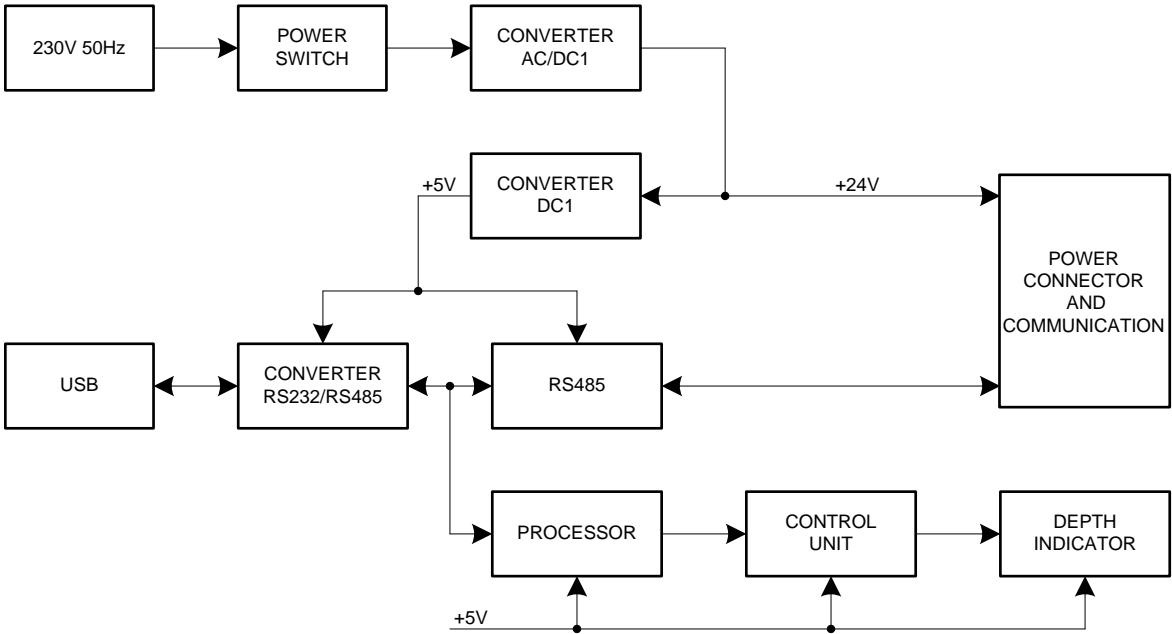


Fig.3. Block diagram of the unit supply – communication.

The underwater communications system antenna is used for sending and receiving a Reson TC 1026. The measured sensitivity of the receiving antenna is about 131dB re 1 $\mu$ Pa / V at 1m to 36kHz frequency. Capacity of the antenna is 7.9 nF. [1]

Hydroacoustic modem antenna is designed to transmit and receive FSK signal. The signal frequency is 32kHz log.0, and the signal frequency is 34kHz log.1. Signal with a frequency of 36kHz is used to initiate cooperation between the ship laptop modems and fixed in the measuring device. 36kHz frequency signal is received by the channel duty apparatus.

Fig.4 shows a view of the antenna transceiver modem hydroacoustic



Fig.4. Antenna transceiver modem hydroacoustic.

#### 4. CHARACTERISTICS OF HYDROACOUSTIC MODEM

Schematic diagram of the electronic system hydroacoustic modem is identical in both the modem and a portable desktop. Fig.5 shows a block diagram of the electronic of hydroacoustic modem.

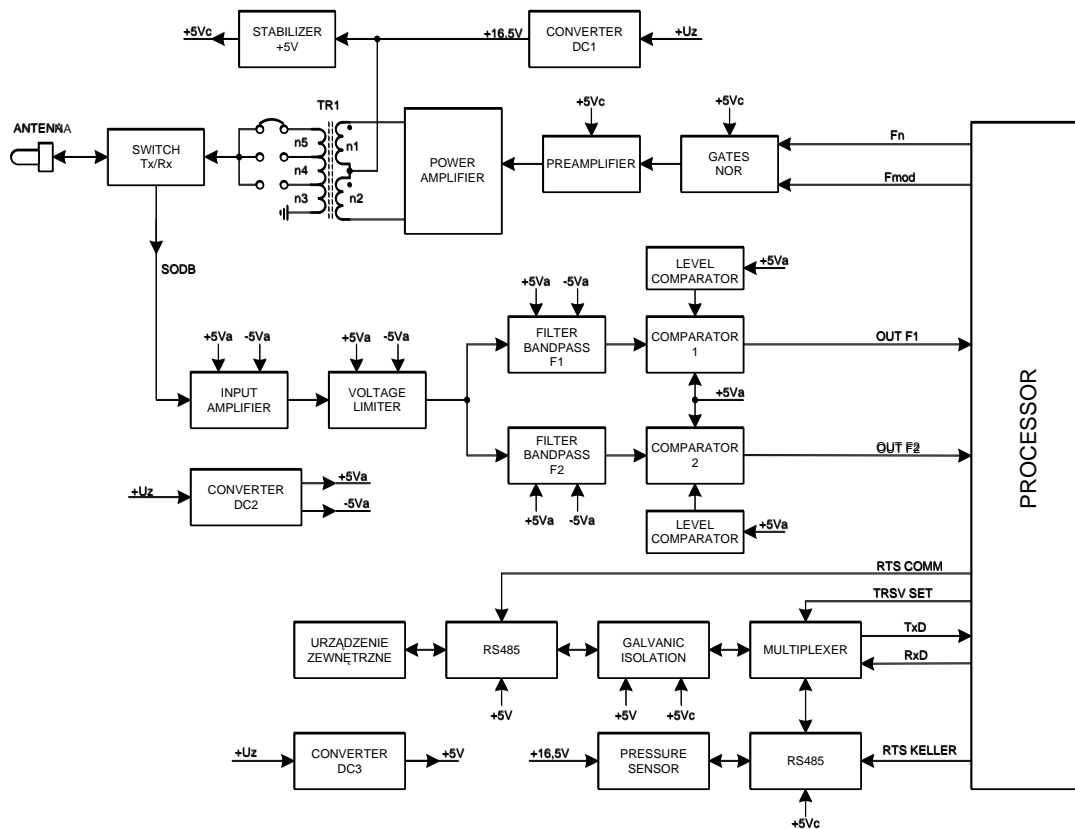


Fig.5. Block diagram of the electronic of hydroacoustic modem.

Hydroacoustic modem electronic system (Fig.6) consists of the following components:

1. Receiver system comprising:
  - input amplifier circuit;
  - voltage limiter circuit;
  - system of band-pass filter F1;
  - system of band-pass filter F2;
  - comparator circuit 1;
  - 2 comparator circuit;
  - DC2 converter with output voltages 5Vc and -5Vc;
2. Transmitter system comprising:
  - NOR gates system;
  - preamplifier circuit;
  - amplifier circuit;
  - switch Tx / Rx;
  - DC / DC converter;
  - voltage stabilizer system 5 Vc
3. System 485 processor with a link that contains:
  - multiplexer circuit;
  - Two RS485 systems;
  - Digital system with galvanic isolation;
  - DC3 voltage converter (output voltage 5 V)

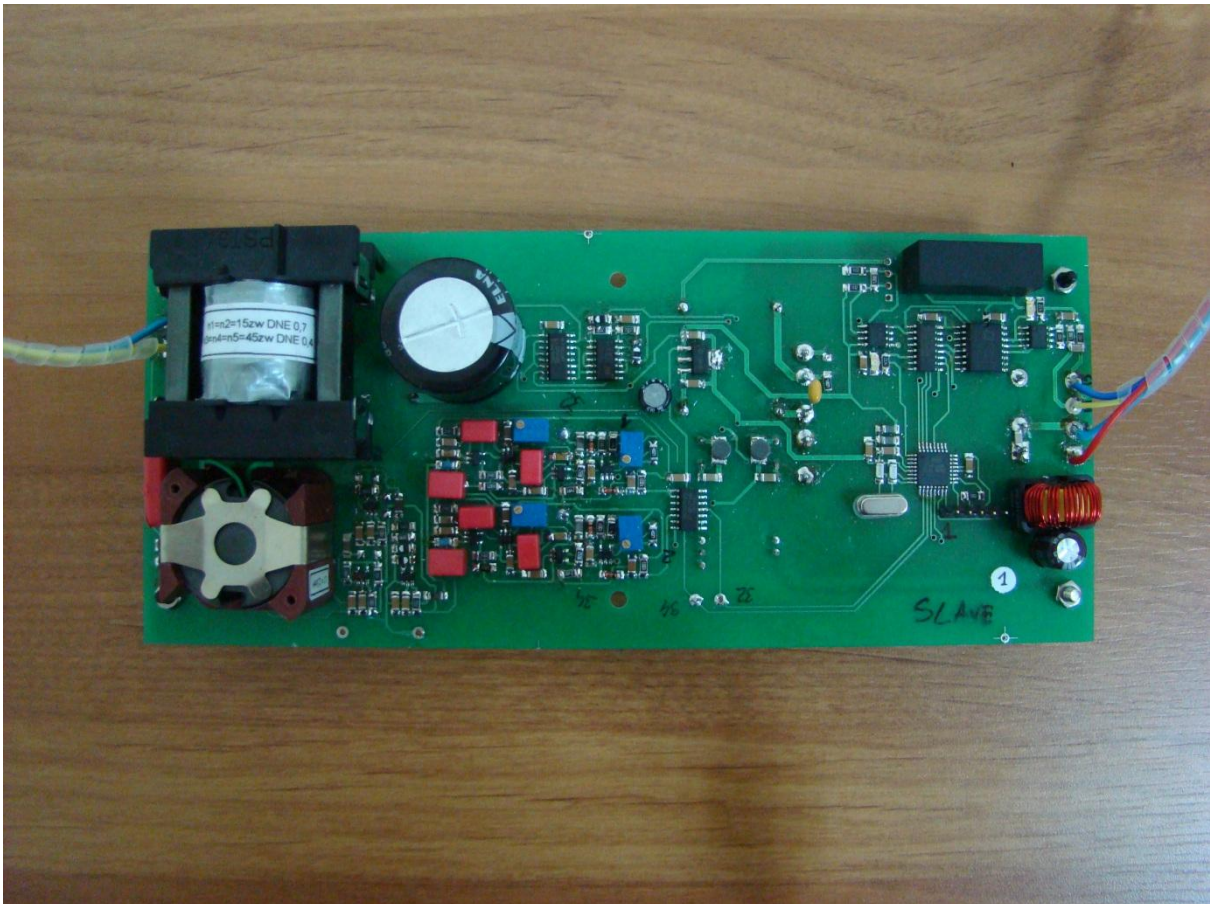


Fig.6. The printed circuit board of the system modem hydroacoustic.

## 5. THE ELECTRONICS OF THE RECEIVER

Fig.7 shows a block diagram of the electronics of the receiver. In principle, the signal received by the receiver system is impulsive. These are the burst sine wave with a frequency  $F1 = F2 = 32\text{kHz}$  and  $34\text{kHz}$ .

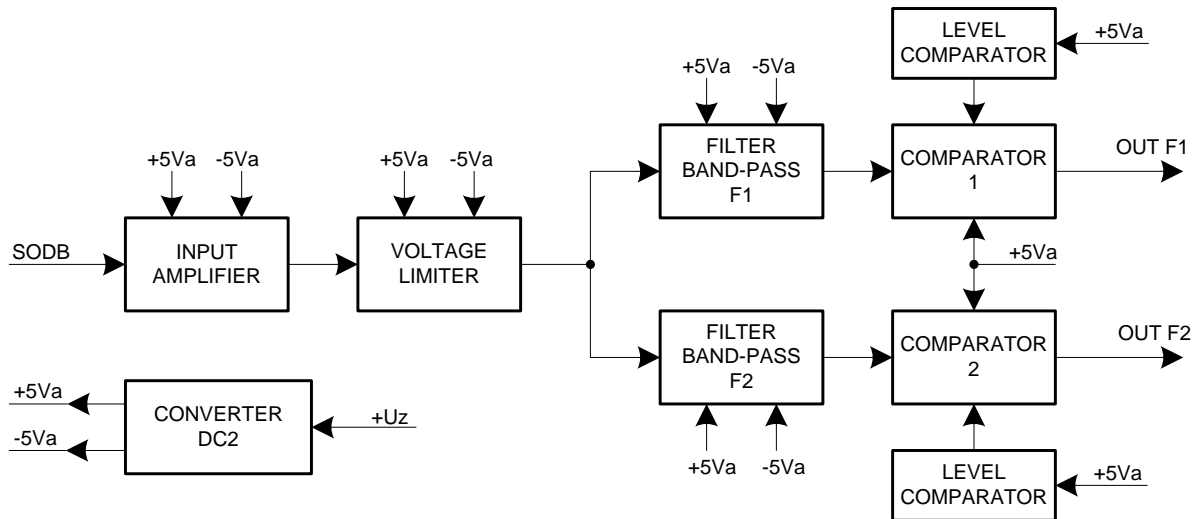


Fig.7. Block diagram of the receiver.

The receiver includes two band-pass filters with resonance frequency  $F1=32\text{kHz}$  and  $F2=34\text{kHz}$ . Filter frequency is  $32\text{kHz}$  signal representing  $\log.0$ , and the frequency of  $34\text{kHz}$  -  $\log.1$ .

Fig.8 shows the waveforms at the receiver system for the two signals with a frequency  $32\text{kHz}$  and  $34\text{kHz}$  waveform  $U_{IN}$   $34\text{kHz}$  channel and showing the following courses:

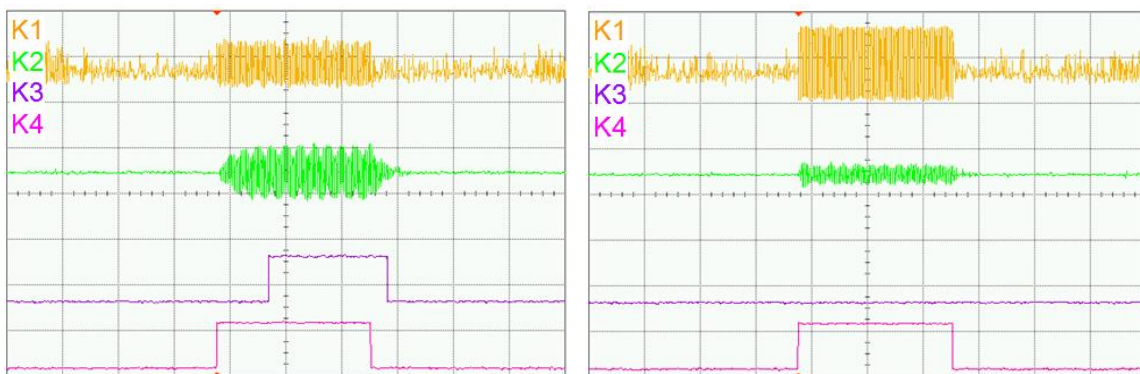


Fig.8. Waveforms from the receiver for the signal  $34\text{kHz}$  and  $32\text{kHz}$  to  $34\text{kHz}$  channel.

K1 - voltage waveform at the output of the voltage limiter circuit  $200\text{mV/div}$

K2 - voltage waveform at the output of the band-pass filter  $34\text{kHz}$   $1\text{V/div}$

K3 - voltage waveform at the output of the comparator  $5\text{V/div}$

K4 - Fmod waveform  $5\text{V/div}$

## 6. THE ELECTRONIC TRANSMITTER

Fig.9 shows a block diagram of the transmitter, which is intended to strengthen the current waveform from the processor and generating a signal via the transmitter antenna.

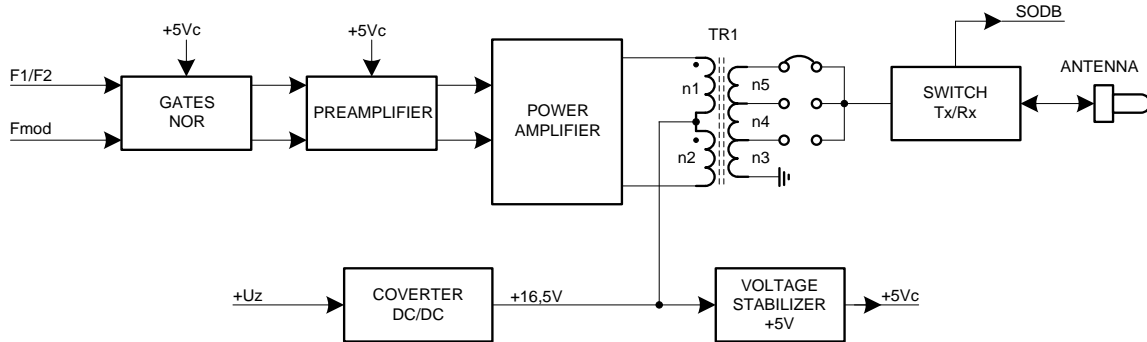


Fig.9. Block diagram of the transmitter.

The effective power of the antenna (output) can be calculated with the following formula:

$$P = \frac{U_a[V_{pp}] \times I_a[A_{pp}]}{8} [W] \quad (1)$$

where

$U_a$  – peak to peak voltage measured at the terminals of the antenna [pp]

$I_a$  – peak to peak current in the antenna in [App]

## 7. OPERATION OF THE COMMUNICATION SYSTEM IN THE LABORATORY

In the laboratory tests, a number of signal transmission, in an anechoic pool measuring between two modems. Fig.10 shows a received signal, which contains 4 bytes of the form:

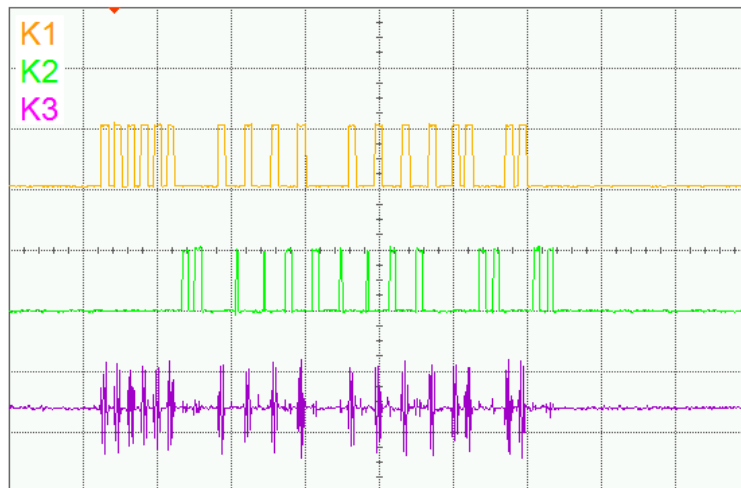


Fig.10. Waveforms at the receiver system modem (50ms/div).

K1 – the waveform at the output of the comparator 34kHz 5V/div

K2 – the waveform at the output of the comparator 32kHz 5V/div

K3 – the waveform at the output of the band-pass filter 34kHz 1V/div

The transmitted signal looks like: 1111100 10101010 01010101 11001100, and the received signal: 1111100 10101010 01010101 11001100.

## 8. OPERATION OF THE COMMUNICATION SYSTEM IN MARINE

Testing communication between the modems were at different times in the pool Gdynia marina and next to one of the channels of the Gdańsk Shipyard.

Tests in Gdynia marina was performed for different distances between the modem and the various parameters of the transmitted signal and the receiver work levels. One slave modem was placed on a yacht Windspeel, and served as a receiver. Connected to the oscilloscope and recorded the signals received.

The second master modem, was located in different places in the harbor. In the master was possible to change the parameters of the transmitted signal, such as the duration of the bit time interval between bits and bits.

### MEASURE 1

Master just 100m from the slave assigned 4 bytes (32 bits), bit 2ms duration, the time interval between bits 12ms, repeated every 2 seconds, the power of 34W.

The transmitting antenna was located at a depth of about 2m (basin depth of about 5m), about 70m from the waterfront.

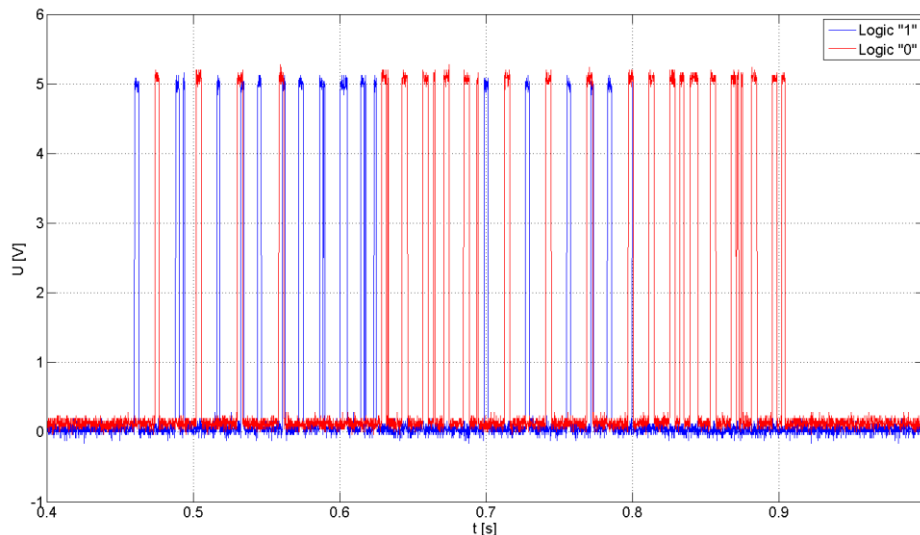


Fig.11. The signal received, 4 bytes distance 100m bit duration 2.0 ms.

The transmitted signal looks like: 01010101 00001111 10101010 11111111, and the received signal: 010?0?00 00011111 101010?0 ?1111111.

The signal was received with errors that are caused by multipath propagation of acoustic waves in the water. The incident wave directly reaches the shortest way to the receiver. Then reach waves reflected from objects located near the transmitter or receiver. This waves are most important because the level is comparable to the direct wave reaches the receiver and cause the faulty operation of the detection, extending the duration of the bit.



## MEASURE 2

Master remained in an unchanged position, were given 4 bytes (32 bits), the bit duration 1.1 ms, the time interval between bits 12ms, repeated every 2 seconds, the power of 34W.

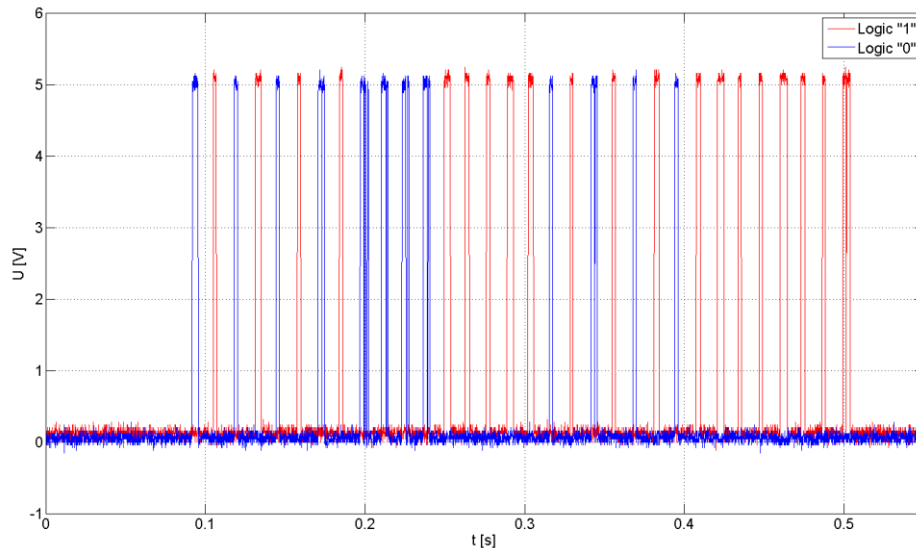


Fig.12. The signal received, 4 bytes distance 100m bit duration 1.1 ms.

The transmitted signal looks like: 01010101 00001111 10101010 11111111, and the received signal: 01010101 00001111 10101010 11111111

The signal was received correctly.

Shortening the duration of the bit caused the reflected signals do not lengthen the duration erroneously received bit on the detector, and there were no moments of overlapping bits in succession.

## MEASURE 3

The measurement was performed in the harbor channel. Master modem placed in a distance of about 400m from the slaves were given 4 bytes (32 bits), 2ms bit duration, the time interval between bits 20 ms, repeated every 2 seconds, the power of 100W.

The transmitting antenna was located at a depth of about 2m approximately 1m from the waterfront.

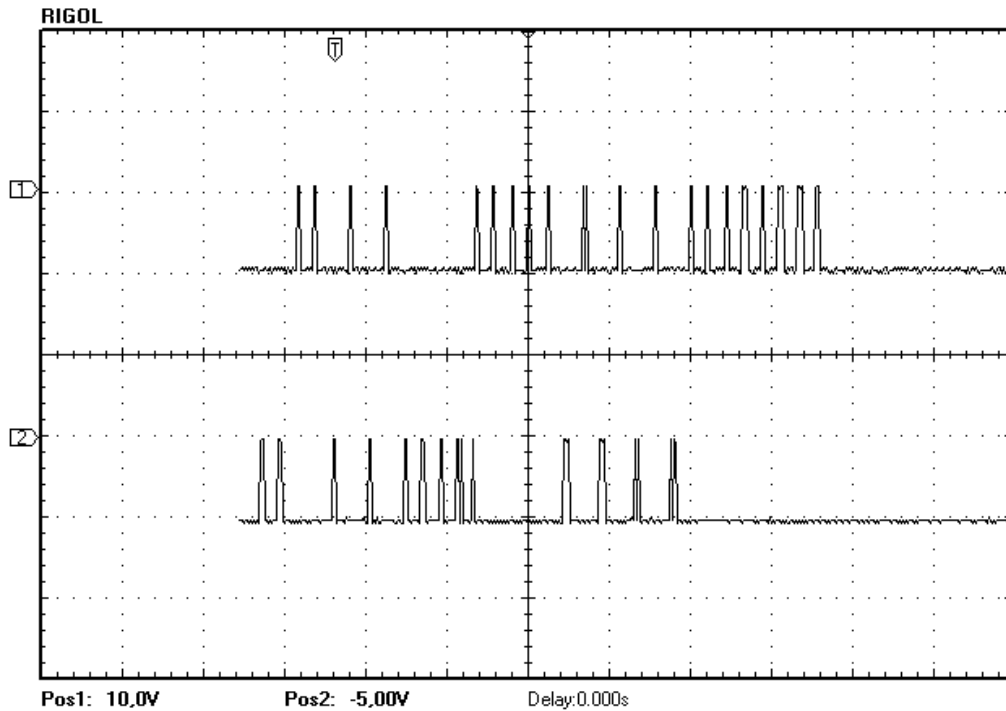


Fig.13. Received signal, 4 bytes, 400m distance, 2ms bit duration, the repetition time of 20ms.

The transmitted signal looks like: 00110101 00001111 10101010 11111111, the received signal: 00110101 00001111 10101010 11111111. The signal was received correctly.

The reflections of the harbor channel does not have great significance for signal reception because the reflected wave from the wharf was in a direction perpendicular to the expected direction of wave propagation.

Marine conditions are closer to those prevailing in the harbor channel in the sea there are no walls are close to the transmitter or receiver and reflected signals are not as significant as in the dock. The results obtained are satisfactory, and it can be expected that the system will check in sea conditions. [2, 3, 4]

## 9. COMMAND SENT BY THE COMMUNICATION DEVICE:

Initiating the exchange of data lies with the master module. The module located under the surface of water only respond to inquiries.

In order to initiate the data exchange surface vessel module sends a signal duration one byte at a frequency of 36kHz asking. The unit of observation is then detected omnidirectional band for call sign 36kHz signal. The measuring module sends the information of detection initial frequency to the master module. This signal activated all systems of the communication module. The transmitter is activated and transmitted standby signal:

11001100 - CCh

When the master module does not receive a standby signal within 3 seconds (setting range no greater than 2km) followed by re-initiation. Five failed attempts causes the appearance of the message that it can not connect. The operator has the option to retry the initiation or cessation and change the place of trial.

Underwater unit ready signal after transmission waits for a command from an offshore unit, when this does not answer, for example, 30 seconds (time counts cRIO) module CRIO off underwater (cuts off the power supply). In order to wake up again to send the signal trigger.

The communication module is transparent to the transmitted information, that is, all commands received by the module are sent unchanged to the master module (CRIO) via RS-485. Master Module (CRIO) send all responses by RS-485 to communication module. Command sent by the underwater communication:

- Your battery
- The ascent module
- Turn off all sensors
- Turn on all the sensors (including measurements)
- Check the operation of all sensors (TEST)
- Turn off sensor number X
- Turn on the sensor number X
- Check the amount of free disk space
- Ascent communication interface
- Immerse the communication interface
- When the battery is low, rather than a standby signal, transmitted is the low battery signal. Next, depending on the battery status communication module enables normal data. When the battery is critical to the communication module only allows to:
  - the ascent module
  - the exclusion of all modules

Commands given to the initialization signal is received instead of signal mode:

- Low battery (priority)
- Critical battery status (priority)
- Low Disk Space (less than one day registration)
- Out of disk space
- Improper operation of one of the modules do TEST

Data transferred between the module and the underwater surface ships, protected against errors (Hamming code and CRC) allows detection two errors and correction one error. When the communication module detects an error or receives a signal that is not in the book sends an error code 00010110. After three government of error signal is received refrain from further transmission module and displays the information about transmission errors. Please change the location of transmission or increase the power of broadcast.

## ACKNOWLEDGMENTS

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