# THE DEVELOPMENT OF SERVICE AND UNDERWATER ROBOTS, USING NETWORK AND 3D-VISION TECHNOLOGIES

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**Abstract:** *The work is devoted to the creation of underwater robotic systems. The structure of the robotic complex and the composition of the main subsystems, included in it, are considered. The advantage of dividing the whole complex into three components are shown: central control unit (CCU), well-traversed base-station (BS) with limited mobile opportunity, but connected to the CCU by a cable and highly maneuverable fully autonomous modules (AM) directly performing underwater work. Thus, maximum realization of the advantages of the hardware construction of the complex is possible by using the contactless method of charging the onboard batteries AM directly in the working area, without the need to be back to the surface. The possibility of dividing the AM control channel into cable and hydroacoustic parts, as well as the use of several variants of technical vision for the organization of BS and AM control in the case of sufficient water transparency in the working area, is also shown.*

**Key words:** *: Underwater walking robotic complex, 3D-vision systems, contactless power supply, information support of the control process.*

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## 1. Introduction

The solution of a whole range of typical tasks and complex work on the sea bottom or near the bottom in extreme conditions, especially the performance of work at great depths are currently entrusted to robotic devices. These devices represent a whole complex of connected and interacting systems for various purposes, the main of which are:

- the device providing movement under water;
- navigation and control system;
- system of information support of control processes;
- communication system with supervising operator, working from the central control unit;
- power supply system of the underwater complex;
- system of rapid transfer of large amounts of accumulated information from autonomous modules to the base-station and then to the central control unit;
- robot emergency self-rescue system.

To perform a large list of underwater works, the effective structure of the hardware construction can be the representation of the entire system by three components. It is a central control unit with an supervising operator (CCU), a relatively sedentary unmanned base station (BS) connected to the CCU by cable and fully autonomous highly maneuverable modules (AM) directly performing underwater work [5]. Such hardware construction of the robotic system gives a number of fundamental advantages and ultimately significantly expands the operational capabilities of the robotic complex [4]. With this arrangements, the robotic complex (RTC) will combine the following systems.

## 2. A devices, that provides underwater movements

For reliable delivery of the BS to the place of underwater works, a walking device was chosen, which has the best characteristics, when overcoming obstacles encountered on the sea bottom, in particular, which can provide a maximum pulling force of 1.5-2 times its own weight.

## 3. Navigation system for movement control

Since the BS is connected to the CCU by a cable, the task of controlling its movement is solved in the traditional way: a TV cameras with floodlights on board the BS and a television monitor (or/and special patented 3D-system) for the operator in the CCU, which controls the movement of the BS by commands transmitted over the cable. Thus delivery of BS to the place of carrying out works is made. The navigation system provides the orientation of the BS and AM under water and the calculation of their coordinates. It also includes an electronic compass, gyroscope, signal beacons on the BS and on each AM.

## 4. System of information support of management process

The system provides current information about the position of the AM relative to the surrounding objects on the bottom in the working area.

For the case of sufficient water transparency, the system of technical vision (STV) proved to be very effective. Innovative technology of STV provides search, identification and analysis of spatial location of objects in difficult conditions of application, including the basis of the analysis of stereo television images in the working area. This system is implemented in 2 main areas – for service robotics and for underwater conditions. Several modifications of the STV were tested:

- measuring the speed of BS, by using linear photoelectric devices, scanning the space during movement of the robot;
- system for recognition and measurement of coordinates and angles of orientation of objects based on color gradients of the image;
- system of shape recognition and measurement of geometric parameters of objects using structured illumination;
- measuring system with a video processor integrated into the television camera for high-precision measurement of spatial coordinates;
- system of recognition of the form of objects, measurement of their parameters, and spatial positions with training by the implemented method of displaying the visual data.

Some of the results obtained on these options STV:

- the error in detecting the linear objects coordinates - not more, than 1/20000 of the field of view area;
- the error of measurements of angular coordinates - no more than 0.1 degrees;
- simultaneous measurement of the three linear and three angular coordinates of objects;
- number of recognized and measured objects in the field of view - up to 32 objects;
- hierarchical complexity of the form of objects - at least 16 levels;
- frequency of information output - from 30 to 120 Hz (for linear measurements - up to 2 kHz);
- illumination of the working stage - from $10^{-4}$ Lux to $10^{+5}$ Lux;
- information interface-Ethernet (1 Gb/s), USB, RS-485/232;
- dimensions of the measuring camera - not more than 60 x 60 x 40 $mm^3$;
- the weight of the measuring camera-not more than 200 g.

The main differences between the developed STV technologies are the combination of hardware and software for real-time image processing, high-precision (sub-pixel) measurements of spatial coordinates of moving objects, methods of training and recognition of complex scenes.

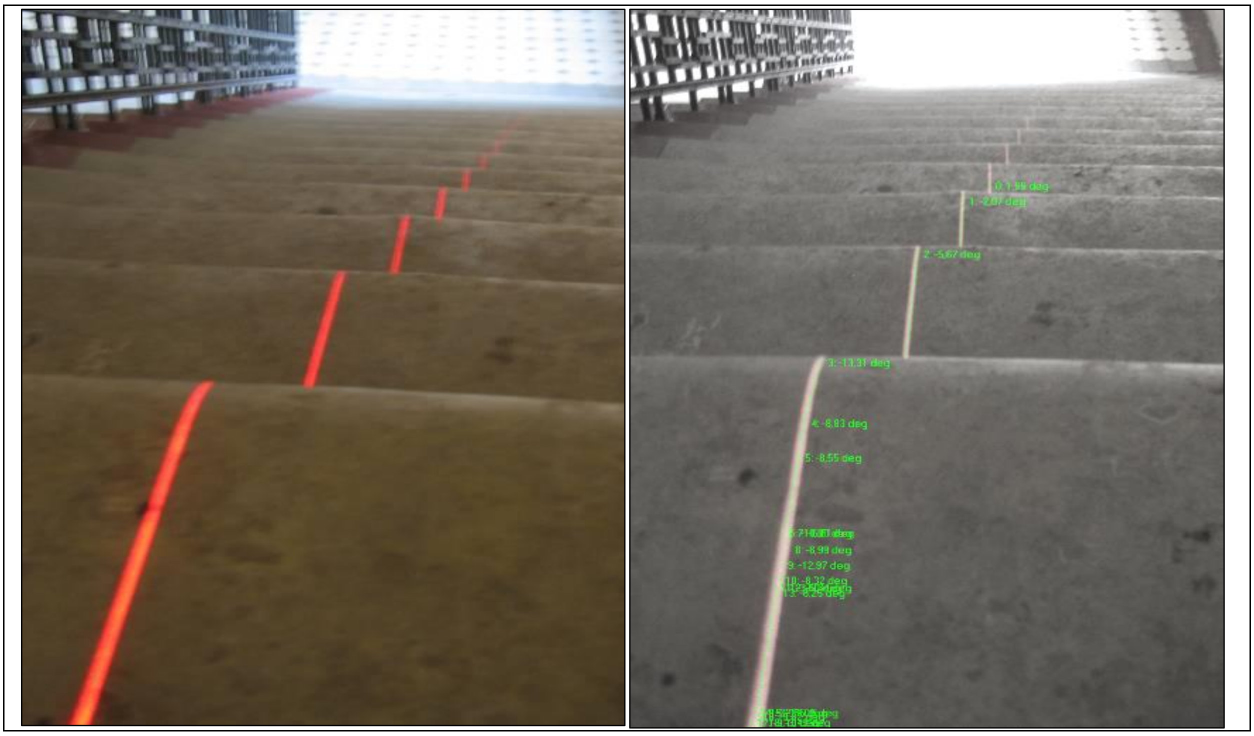

Fig. 1. Example of measurements, processed by STV: a) original image of stairs b) coordinates and height of steps.

Taking into account the high probability of turbidity of the working area, in addition to the TV-cameras, robots were equipped with ultrasonic location devices (course and side view), including both receiving and transmitting equipment and microprocessors for primary processing of the receiving signals.

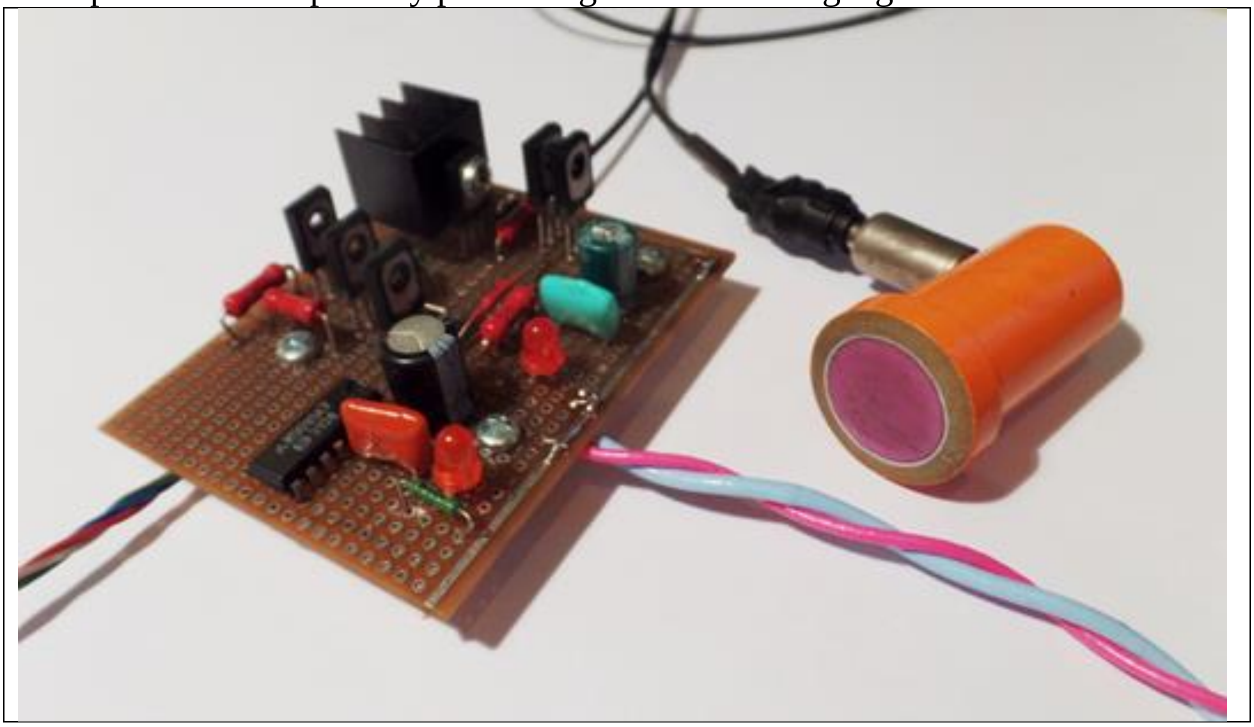

Fig. 2. Board of ultrasonic generator of course sonar with emitter forming ultra-shot signals.

## 5. Communication system with the operator of the central control unit

The communication of the CCU with the BS is represented by a television channel over cable. It provides the removal of BS in the working area.

Communication of AM with CCU is organized by means of relay through BS. From AM to BS - on a narrowband ultrasonic channel, and from BS to CCU – through a cable. On this channel is undertaken operational governance of movements and functional actions of AM.

## 6. Power supply system of the underwater complex

The primary source of energy has a CCU, located on a watercraft or on the shore. It is assumed that the customer can choose (depending on availability) the power grid, on-board ship network, or mobile power generator, or a powerful battery. Power supply of drives of running motors of BS, and also power supply of its electronics is made through the unwinding logging cable from CCU.

The power supply of the motors and all the electronics AM organized from the own on-board batteries. Moreover, their periodic automatic recharging is carried out in a contactless way from the BS without surfacing, directly in the working area. For this purpose, radiating and receiving devices were developed and installed on the BS and AM respectively.

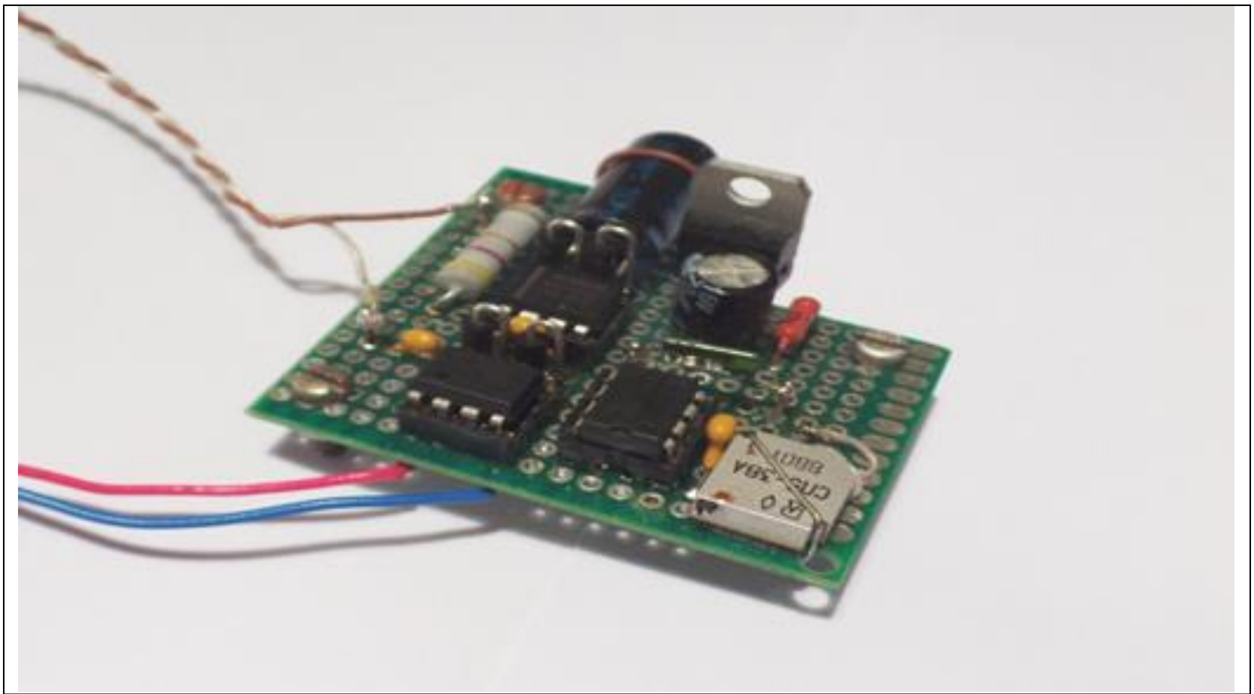

Fig. 3. The board of the master generator of the radiating device contactless power supply systems.

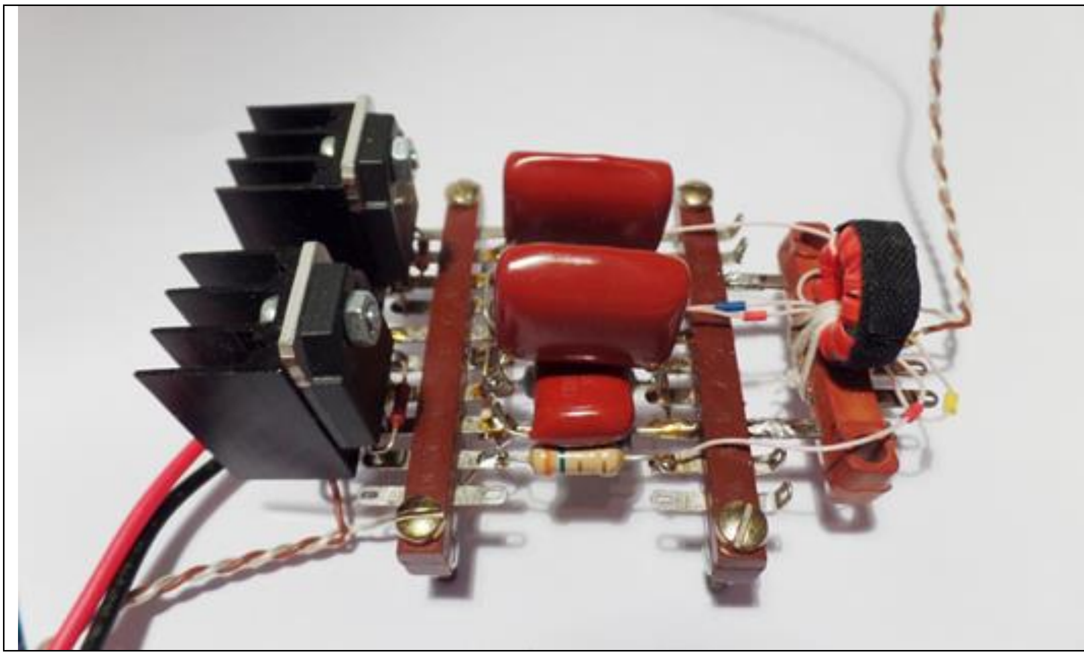

Fig. 4. The generator of the radiating device of average power contactless power supply systems.

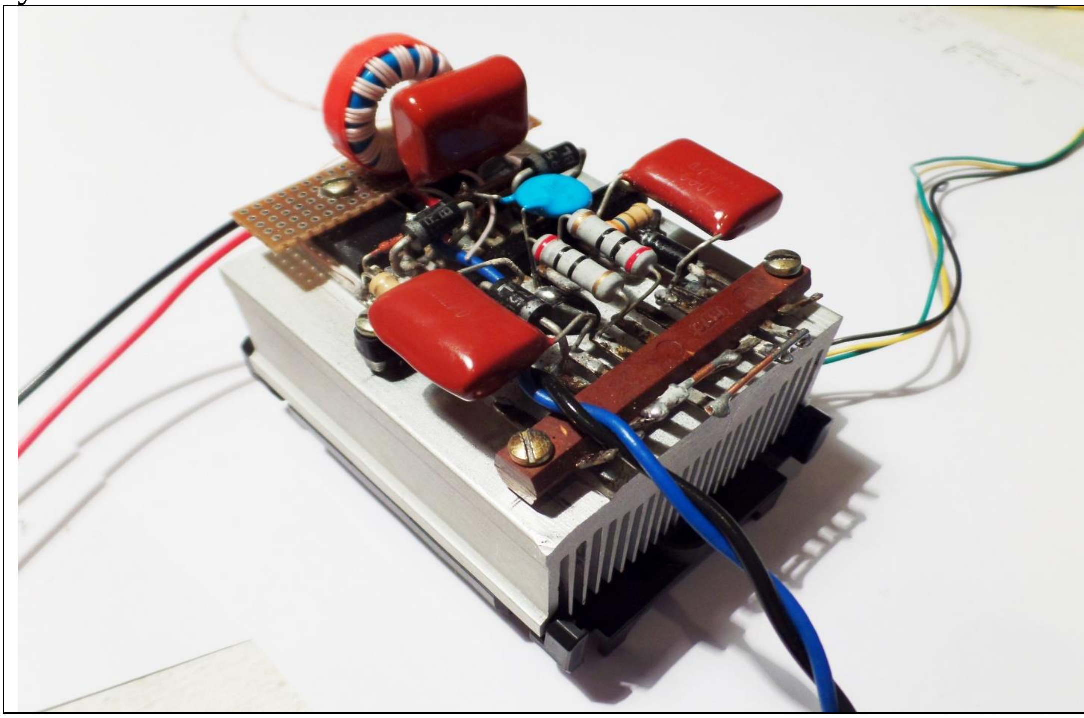

Fig. 5. Generator of the radiating device of the increased power contactless power supply systems

## 7. The system of accumulation and rapid transmission of large amounts of information

To capture large amounts of information, for example, the results of long-term observation of any processes produced by research buoys, it is proposed to use an automatic contactless method of transmitting information flow over a radio channel in the range of 1-2 GHz.

At the same time, the transmission range in salt water is limited to a few centimeters, which is quite enough, if AM approaches the research buoy or the BS. It should be noted, that a significant attenuation of radio waves at ranges exceeding several tens of centimeters completely eliminates the possibility of unauthorized listening.

## 8. Emergency self-rescue system AM

Performing work in extreme conditions, such as work under water, especially at great depths is associated with the risk of accidents. Appropriate measures should be taken to save expensive equipment. Especially at risk of AM loss. To detect an AM, that has lost control, an ultrasonic radiation beacons have to be installed on its board, powered by a built-in independent power source. The ultrasonic signal is emitted periodically and contains an individual AM number. In addition, the system have to be equipped with a specialized AM, having on its board a powerful battery of batteries with a radiating device for contactless charging and a cutter for cutting networks, that interfere with the rescue. Such a specialized AM is able to make a contactless emergency recharge at a distance from the BS in case of an abnormal discharge of the onboard battery of the emergency AM and remove it, entangled in fishing nets. Also, each AM is equipped with an emergency float, ejected in the event of an accident.

Currently, the following tasks have actually been tested with positive effect and implemented:

- walking system for BS, improved installation of electric drives with smooth speed control, which allowed to significantly expand the functionality of overcoming obstacles, when driving on the sea bottom or on a seashore.
- architecture of software supervising control of power drives of BS thrusters by cable using TV camera,
- non-contact recharge charger for AM on-board batteries with high power,
- AM control information supporting system, using ultrasonic directional sonar and side-view sonar in conditions of limited visibility due to muddy water,
- several variants of STV (land and water),
- the system of transmission of a large amounts of information from AM to BS (and back) by the radio channel in salt water.

The full-scale tests of the main elements of the underwater robotic complex on lake Baikal and in the White sea showed the efficiency of the proposed solutions and great prospects for the use of RTK in the offshore zone to search for various objects and transport them to the shore.

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