Questions of type selection of lighting devices for underwater telecommunication television systems

V L Martynov¹, I L Skripnik², Yu G Ksenofontov³, T T Kaverzneva³ and K V Pshenichnaya⁴

¹ Admiral Makarov State University of Maritime and Inland Shipping, 5/7, Dvinskaya st., Saint-Petersburg, 198035, Russia
² Saint-Petersburg University of State Fire Service of EMERCOM of Russia, 149, Moskovskiy pr., Saint-Petersburg, 196105, Russia
³ Peter the Great Saint-Petersburg Polytechnic University, 29, Polytechnicheskaya st., Saint-Petersburg, 195251, Russia
⁴ Saint-Petersburg State Marine Technical University, 3, Lotsmanskaya st., Saint-Petersburg, 190121, Russia

E-mail: ksenofontov.ura@mail.ru

Abstract. The problems of studying the underwater part of the water area through the lens of ecology exist all over the world. Difficulties associated with the study of the ecological state of the hydrosphere pose for modern engineers the task of developing specialized autonomous underwater robotic systems, as well as using telecommunication means to transfer information from them to the shore or ship. Due to the fact that visibility under water has a limited range, that is, it is possible to observe underwater objects only from a close distance, it is proposed to use underwater telecommunication television systems that function in conjunction with lighting devices. The article presents the results of an experiment carried out in a marine aquatic environment, on the basis of which the expediency of using light searchlights and laser devices in the near and far zones in underwater search systems is substantiated.

1. Introduction

Environmental regulation around the world is becoming increasingly important and is aimed at developing criteria for all types of harmful effects. The most promising direction is the preparation of complex biological criteria that take into account the impact of all pollutants present in the aquatic environment. The solution to this problem is difficult due to the complexity of underwater research, identification of hazardous objects in the hydrosphere [1-5].

When assessing the environmental safety of newly designed offshore facilities, the availability of information on the state of the underwater environment after the facility is put into operation is of decisive importance [6]. Naturally, given the level of development of information technology in our country, obtaining and transmitting the necessary information about the ecological state (for example, the degree of pollution of the sea bed), including from automated robotic systems, are impossible without modern telecommunication systems for underwater search [7, 8].
2. Materials and methods

Today, television systems have gained particular popular appeal in obtaining information about the state of the hydrosphere. They are the ones that are able to identify detected underwater objects with high quality and resolution, visually determine the state of protective barriers separating, for example, sources of radioactivity from the external water environment, for inspecting underwater objects, visually controlled gamma spectrometric measurements and sampling, which allows obtaining timely data on the state of the underwater marine environment and flooded objects. Problems requiring decision-making in connection with the need to visualize processes and objects are encountered not only in the aquatic environment. For example, constructors of high-rise buildings face low visibility conditions in the air [9-11].

When carrying out an underwater search, such systems are usually not used without devices providing intense light radiation, therefore, in addition to them, both conventional light projectors and special illuminators implemented using laser technologies are used. The economic analysis showed that the additional financial costs for installation and operation with the possibility of their improvement are fully justified. Only thanks to the tremendous efforts of engineers, scientists and modern scientific achievements over the past 10 years, a significant scientific “breakthrough” in this sector has been achieved: the detection range of an object under water with the joint use of a laser light device was able to reach the value \((1.5 \div 2) Z_b\) with \(0.7 Z_b\) (\(Z_b\) is the distance that determines the visibility of “Secchi disk” in the marine environment, m), which was more than 2 times [12]. Nevertheless, the financial side of the issue did not allow obtaining the required tactical and technical characteristics of underwater telecommunication television systems for a long time, and in some cases it simply turned out to be economically inexpedient. Therefore, a group of scientists from leading enterprises of the country developed a program for conducting a certain kind of experiments, during which it was necessary to investigate the possibilities of different operating principles of underwater lighting systems and assess the prospects for using laser technologies in the underwater environment. At the moment, leading experts in the field of television are discussing the issue of increasing the efficiency of underwater search systems, in particular, not only the use of laser technologies for highlighting underwater objects, but also for transmitting a signal containing information about a given object in order to obtain a clear, contrast video with a targeted video resolution. These data on the video image are supposed to be taken from the board of an automated underwater robotic complex and transmitted to ships or to coastal terminal equipment using the latest laser telecommunication devices [13-17]. Further in the article, the experiment, thanks to which it was possible to formulate the basic provisions and recommendations for using both types of lighting devices under water, is described in detail.

3. Results

During the tests, the coefficient characterizing the entire underwater search system in terms of increasing the distance to the object of observation was taken as the main criterion. This coefficient is directly proportional to the quality of the video image, which should be understood as the information content received by the terminal equipment of the picture, which allows reading all the necessary data about a particular object in the search area. Various kinds of tests during the operation of underwater television systems put forward additional requirements for a special telecommunication device, which is called a “light-to-signal” converter and is responsible for such an important indicator as the resolution, that is, the number of points in a line and the number of lines in the raster itself [18]. It should also be noted that the corresponding image resolution is directly determined by the angle of the field of view, which can be attributed to the characteristics of not the entire system, but only to the telephoto lens. The value of the specified angle for underwater television systems operating in standard mode, as a rule, is in the range of \(10^\circ \div 80^\circ\). Accordingly, when designing underwater telecommunication television systems, developers must take into account the factor that with a decrease in the angle of the field of view, the resolution increases, and, therefore, the range to the object of observation also increases with it. However, in this case, there is some peculiarity: at a very small angle of the field of view during the
operation of underwater search systems associated with determining the presence of moving objects in the aquatic marine environment, especially if the distance to such an object is small, and the process of viewing the zone is continuous, a kind of “blur” of the video image, which reduces the quality of the functioning of the entire underwater system as a whole, may be observed [19, 20]. Based on this, researchers in the field of hydro-optics came to the conclusion that the maximum quality of the video image can be achieved if the criterion of optimality of the coincidence of the angle of the field of view of the TV camera installation (hereinafter TCI) and the angle of illumination are observed. In the most extreme case, the situation is allowed when the angle of the field of view of the light device can exceed the angle of the field of view of the television camera, but not more than 10º–15º. As the practice of recent years shows, tests have been carried out in a marine aquatic environment to increase the visibility range of an object under water while maintaining a given value of the TCI resolution, and its angle of view was about 20º–30º, therefore the participants of the experiment had the opinion that the underwater installation should be equipped with a lens having an angle in the range of 10º–40º diagonally, provided that the angle of illumination of the underwater lamp is slightly larger, by about 10%.

Taking into account the indicated values of the angles, the working group approved a plan for a new experiment, its purpose was to confirm the listed factors and study the operation of the TCI together with underwater lighting installations of two types. The key elements in the experiment were: a black and white TCI TVK-5110, which is designed for underwater search for objects using protective glass, a laser illuminator and a light searchlight of the German brand Dedolight. The block diagram of the operation of the underwater equipment that participated in the experiment is shown in Figure 1. Here, the laser illuminator, taking into account its continuous operation, has the following main parameters: wavelength is 532 nm; radiated power is 2 W; the diameter of the output beam is 3 mm in continuous operation.

**Figure 1.** Block diagram reflecting the operation of the underwater equipment involved in the experiment.

For the experiment a light illuminator of the floodlight type was selected on the basis that the luminous flux emitted by it is 3–4 times higher than that of its analogs at the same power level. In addition, most Dedolight fixtures do not have the effect of “shadow spots” near the center of the light
spot. They have a set of light lamps (usually halogen with an operating voltage of 12 V) of different power: 20, 50 and 100 W. This power spread made it possible to sufficiently change the radiation intensity of the luminous flux. The following indicators were taken as initial data: water transparency is \( \varepsilon = 0.2 \, \text{m}^{-1} \), illumination angles of searchlight and laser illuminators are 6º for searchlight and 0.8º, or 5º for laser.

The task of selecting approximately the same angular divergence of the searchlight (6º) and the laser (5º) was the possibility of comparing them in different observation zones: 17.5 m (near zone) and 25 m (far zone). The geometric dimensions of the corresponding light zones are shown in figure 2.

![Diagram showing light zones](image)

**Figure 2.** Results of the experiment: \( S_L \) is an area illuminated by a laser illuminator; \( S_P \) is an area illuminated by a spotlight.

4. **Conclusion** The analysis of figure 2 allows us to draw the main conclusion: when using automated underwater robotic systems in the near search area (less than 17.5 m), it is advisable to use light illuminators of the floodlight type with illumination angles of 5º and 6º, respectively, on their board, since expensive telecommunication laser equipment does not justify itself economically in this situation. In turn, it is generally recommended to provide far-field illumination in order to improve the performance of search engines using laser lighting devices.

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