Radio Control of Unmanned Underwater Devices

A.V. Nikolaev¹, D.V Fedosov², A.V. Starchenkov³

¹Russian Academy of Sciences, Federal State Budgetary Institution of Science, Institute of Engineering Named after A.A. Blagonravov
²Research and Production Society with Limited Liability HF-Communication
³Open Joint Stock Company Omsk Production Association Radio Factory Named after A.S. Popov

alarmoren@yandex.ru

Abstract. Practical development of easy-to-implement technical solutions for receiving and transmitting a surface electromagnetic wave (SEW) – that passes through the skin layer and propagates within the boundaries of the sea surface in the lower troposphere and the water's edge – from a submerged position will create preconditions for the use of radio control channel in marine systems. The report reveals the topic of SEW using for radio control of unmanned underwater devices and describes the results of design work on the ultra-low radio frequency underwater small-sized antennas.

Introduction

The development of unmanned underwater devices for various purposes necessitates the creation of wireless communication equipment with small dimensions and weight. Hydroacoustic communication channels that satisfy this requirement are sensitive to interference of both natural and artificial origin, especially in the surface water layer. Communication channels based on ultra-long electromagnetic waves (ULW) use antennas that are much larger than the underwater device.

At the same time, the development of technical solutions for the excitation of SEW in the surface layer of sea water by small-sized antenna devices of ultra-low radio frequencies will create the prerequisites for the practical implementation of wireless radio communication [1, 2].

In this case, we want to highlight the main scientific problem in electrodynamics that should be solved, and it consists in the complexity of the theoretical description of the process of SEW generation by small-sized antenna devices in the surface water layer as well as the creation of conditions for the propagation of radio waves within the boundaries of the sea surface in the lower troposphere and the water shoreline.

The report deals with design features of small-sized ultra-low radio frequency antenna devices, reveals some issues of unmanned underwater devices radio control and online transmission of marine environment and lower troposphere parameters.

1. Physical prerequisites

It is known that at certain incidence angles of an electromagnetic wave, SEW appears at the interface between two environments (in our particular case, sea water environment and air environment).

The efficiency of SEW excitation on semiconducting medium surface (for example, soil, sea and fresh water) is influenced by many factors: inhomogeneity of the electrophysical parameters of the soil, the presence of a skin layer, the relief of the soil surface, waves of seas and oceans [3, 4].
The group of scientists from the Institute of Applied Geophysics named after academician E.K. Fedorov theoretically and experimentally investigated the presence of SEW in the microwave electromagnetic waves. The creative group of the Krylov State Scientific Center under the leadership of A.Yu. Andreev experimentally confirmed the presence of SEW at radio frequencies of 10 and 15 MHz in the salt lake Sulfat water area, the radio signal was registered on the route up to 1.2 km.

The engineers of RPSLL HF-Communication and JSC Radio factory named after A.S. Popov created small-sized underwater antenna devices for ultra-low radio frequencies, which were tested in the Omsk region salt lakes. The antenna was submerged to a depth of 30 cm, while the radio signal was recorded at distances of more than 600 m and the communication range was actually limited by the water's edge.

The latter confirms that due to the displacement and conductivity currents excited by a small-sized antenna and caused by the ionic conductivity of the aqueous medium, the skin layer is passed (for seawater $\varepsilon \approx 80$, $\sigma \approx 4.3 \text{ cm/m}$) and SEW is formed at the interface between the two environments.

It has been experimentally confirmed that the zone of radio control of unmanned underwater devices using SEW is limited by the edge of the water basin of rivers, lakes, seas and oceans, as well as by the transmitter power and receiver sensitivity, and the depth of effective radio control will be limited by the radio frequency of the carrier electromagnetic wave and the specific conductivity of water.

2. Work results
We made the resonant antenna that is compatible with both air and water, including salty water, that is, the water environment has very little effect on the antenna. The antenna efficiency measured by the calorimetric method was from 10 to 22% with an antenna size of 0.1-0.7% of the wavelength. At the present time we have made the operating antenna models for frequencies from 300 kHz to several MHz with dimensions less than 0.05% of the wavelength, having a high electrical resistance and withstanding input powers of more than 100 W.

In addition, we have developed a high-quality small-sized antenna with a Q-factor (loss) that changes little when it is immersed in water, which indicates the absence of the effect of shielding and shunting the antenna near-field with water, since losses would reduce the antenna Q-factor.

The key element of the underwater radio control system is a small-sized antenna device of the LW-MW-SW range [5], which has a high efficiency value and is compatible with the aquatic environment. It makes it possible to start experimental checks of quantitative parameters of equipment to determine the tactical and technical characteristics of the system for wireless radio communication on SEW.

3. Near SEW field
A part of the near-field radio waves for small antennas will be above sea surface. When studying the processes of generating radio waves by small-sized antennas in the near-field zone, a significant difference in the intensity of the fields of the magnetic and electrical components was found when using various small-sized antennas. The difference in amplitude was up to 15-20 dB. Further, after leaving the near-field zone, the magnetic and electric fields of radiation "leveled" and their ratio corresponded to the data from classical electrodynamics.

For example, at a frequency of 50 kHz, the wavelength in water is 670 meters (in air, 6000 m), that is, when the antenna is located in the near-surface layer of water at a depth of several tens of meters, most of the near zone (the place where the radio wave is “born” and generated) will be on the surface, therefore, it is necessary to assess the propagation taking into account the near zone of radio waves, and not the plane wave formed.

4. Other applications of SEW
The technology of transmitting data from under water through the ice cover at depths of up to 20 m can be effectively applied in the Arctic seaport Sabetta (Ob river with average depth of about 16 m) to transmit data on ice drift speed, ice thickness, current speed, water salinity for hydrometeorological support of navigation in a narrow channel 400 m wide, 60 km long, 30 m deep, dug for the
transportation of liquefied gas by a special tanker fleet with a displacement of about 300 thousand tons, year-round.

The introduction of such a technology into the system of hydrometeorological support will immediately give a great economic effect by preventing very likely emergencies when a supertanker runs aground inside an artificial channel.

Alternative options for underwater communication (fiber optic cable) are expensive and unreliable. Radio communication is feasible from the near-surface layer of ocean water, even if there is ice on the surface.

Data transmission for hydrological monitoring from under the ice to the coastal data receiving point will be ensured through the use of lower frequencies 100-1000 kHz (Fig. 1).

![Fig. 1. Illustration of low-frequency (long-wave) radio communication capabilities](image)

**Conclusions**

To ensure the transmission of a radio signal from under the ice, it is possible to use SEW, whose energy is concentrated in the near-surface layer near the interface between two media.

A radio antenna located at a shallow depth generating a SEW in near-surface layer will be able to transmit data to control the steering mechanisms of unmanned underwater devices.

Research confirms that SEW radio control zone in marine systems will be limited mainly by the edge of the water basin of rivers, lakes, seas and oceans, and radio control effectiveness will depend on the transmitter power, receiver sensitivity, frequency of the electromagnetic carrier wave, and the conductivity of sea water.

**References**

[1] V.N. Datsko, Surface electromagnetic waves on metal // Radio engineering and electronics, 2014, v.59, no. 5, p. 452-457.

[2] Y.V. Kistovich, Zenneck surface electromagnetic microwaves in salt water, PhD Diss. in Physics and Mathematics, Moscow, VNIIFTRI, 1988.

[3] V.N. Datsko, New types of surface electromagnetic waves in conducting media, PhD Diss. in Physics and Mathematics, Moscow, GPI RAS, 2000.

[4] V.N. Datsko, SEW antenna, Engineering Physics 2013, No. 8, p.75-78

[5] D.V. Fedosov, A.V. Nikolaev etc., Resonant spiral antenna//Patent RU2680674C 1.