ных веществ. Влияние дна и придонных макроводорослей не должно проявляться на глубинах более 15 метров. Для корректного применения спутниковых данных строго обязательно использование алгоритма MUMM и рекомендуется организация автоматизированной сети подспутниковых наблюдений.

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Ключевые слова: гидрофизический комплекс, сложные низкочастотные сигналы, вертикальная гидроакустическая антенна, широкополосный гидроакустический излучатель, внутренние гравитационные волны**.**

Пивоваров А.А., Самченко А.Н., Швырев А.Н., Ярощук И.О. ИСПОЛЬЗОВАНИЕ ГИДРОФИЗИЧЕСКОГО ИССЛЕДОВАТЕЛЬСКОГО КОМПЛЕКСА В НАТУРНОМ ЭКСПЕРИМЕНТЕ НА ШЕЛЬФЕ ЯПОНСКОГО МОРЯ // Подводные исследования и робототехника. 2020. № 2 (32). С. 56–61.

Осенью 2019 года на шельфе Японского моря в заливе Петра Великого проводился комплексный натурный эксперимент с целью изучения влияния внутренних волн на распространение сложных низкочастотных сигналов. Экспериментальные работы проводились с помощью нового гидрофизического исследовательского комплекса. В состав комплекса входили: вертикальная 8-элементная приемная антенна, автономная широкополосная излучающая станция, многоэлементные термогирлянды и регистраторы гидростатического давления. В течение суток проводились излучение и прием пакетов различных ЛЧМ и фазоманипулированных сигналов с одновременным измерением характеристик поля внутренних волн по трассе распространения. В ходе выполнения натурного эксперимента были подтверждены технические характеристики гидрофизического исследовательского комплекса и получен опыт проведения комплексных океанологических экспериментов. Выявлены различия в использовании линейных частотно модулированных и псевдослучайных фазоманипулированных сигналов, показано характерное на данной акватории, влияние гидрологических возмущений на распространение акустических сигналов. Осенью 2019 года на шельфе Японского моря в заливе Петра Великого проводилось экспериментальное тестирование гидрофизического исследовательского комплекса. Изучалось влияния внутренних волн на распространение сложных низкочастотных сигналов. В ходе выполнения натурного эксперимента были подтверждены технические характеристики гидрофизического исследовательского комплекса. Выявлены различия в использовании линейных частотно-модулированных и псевдослучайных фазоманипулированных сигналов, показано характерное на данной акватории влияние гидрологических возмущений на распространение акустических сигналов.

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Ключевые слова: системы подводного видеонаблюдения, вариации подводных течений, морское волнение, искусственные и естественны маркеры подводных течений, обработка видео.

Фищенко В.К., Зимин П.С., Голик А.В., Гончарова А.А. ИСПОЛЬЗОВАНИЕ СИСТЕМ СТАЦИОНАРНОГО ПОДВОДНОГО ВИДЕОНАБЛЮДЕНИЯ ДЛЯ ОЦЕНИВАНИЯ ПАРАМЕТРОВ ПОДВОДНЫХ ТЕЧЕНИЙ И МОРСКОГО ВОЛНЕНИЯ // Подводные исследования и робототехника. 2020. № 2 (32). С. 62–73.

Системы стационарного подводного видеонаблюдения, разработанные в ТОИ ДВО РАН, помимо решения задач наблюдения за состоянием морской биоты прибрежных акваторий залива Петра Великого (Японское море) могут применяться для оценивания характеристик морского волнения и подводных течений. Эти характеристики важны как в контексте сопровождения наблюдений за жизнедеятельностью морских организмов информацией о гидрологических условиях их существования, так и сами по себе – как важные параметры состояния природной среды. В статье рассмотрены несколько методик измерения сигналов вариаций подводных течений и оценивания на их основе частотных свойств поверхностного волнения. Основная идея состоит в отслеживании на основе анализа видео горизонтальных движений легких маркеров под воздействием на них течений. В первой части работы приведены примеры использования искусственных маркеров двух видов – закрепленных на тонкой нити теннисных шариков с небольшой положительной либо отрицательной плавучестью и установленных на дне вертушек. Показано, что при небольших глубинах установки камер частотные свойства сигналов горизонтальных движений маркеров хорошо воспроизводятся в сигналах поверхностного волнения в диапазонах ветровых волн, корабельных волн, волнения зыби, сейшевых колебаний уровня моря с периодами от десятков секунд до десятков минут. Во второй части работы рассмотрены технологии измерений, основанные на использовании естественных маркеров–полей органических и неорганических взвесей, перемещаемых водными потоками перед камерой, либо растительности, изменяющей свой наклон под действием течений. Они могут применяться при отсутствии либо выходе из строя искусственных маркеров.

ABSTRACTS

Key words: underwater acoustic communication, carrier frequency, underwater acoustic telemetry, underwater acoustic data exchange.

Kebkal K.G. NUMERICAL MODELING OF HIDING PROPERTIES OF UNDERWATER ACOUSTIC COMMUNICATION SIGNALS WITH LINEAR SWEEP OF THE CARRIER // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 4–12.

Based on the results of the numerical modeling, the vanishingly small differences between the probability distributions of the envelope and phase of the sum of Gaussian noise and (weak) underwater acoustic signal with linear carrier sweep,

and the same distributions for the Gaussian noise all alone are demonstrated. Utilization of the continuous spectrum spread of the communication signal may be applied to the task of covert data exchange, where detection of the communication session by the intercepting equipment must be complicated or impossible. Using numerical models, we analyzed the capabilities of implementation of the signals with continuous spectrum spread for covert digital underwater acoustic communications through the standard underwater acoustic transducers, which are in service on the operational ready vessels.

Key words: autonomous unmanned underwater vehicle, deep-sea studies, marine expedition, monitoring of marine bottom ecosystems, navigation complex, software.

Babaev R.A., Bolovin D.A., Borejko A.A., Borovik A.I., Vaulin Ju.V., Konoplin A.Ju., Tregubenko D.I., Mihajlov D.N., Shherbatjuk A.F. AUV APPLICATION TECHNOLOGY FOR STUDYING THE DEEP-SEA ECOSYSTEMS OF THE ATLANTIC SECTOR OF THE ANTARCTIC // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 13–21.

The paper considers the technology of performing the research operations using the autonomous unmanned underwater vehicle (AUV) "MMT-3000". This vehicle was already used in comprehensive research of ecosystems of the Antarctic and deep-sea biological resources of the Southern seas during the expedition of the research vessel "Academic Mstislav Keldysh" in 2020. Proposed technology touches on issues of mission planning, preparing software, AUV control, as well as problems of performing the vehicle submerging and interaction with the crew of support vessels. The features of upgrading the AUV "MMT-3000" are described aimed at providing visual estimations of the density of zooplankton schools in the water column and allocation of the bottom organisms, as well as equipping the AUV with a set of sensors for estimating hydrophysical and hydrochemical parameters of the surrounding environment. The main results acquired during deep-sea missions of AUV are presented as well.

Key words: marine robotic complex, autonomous unmanned underwater vehicle, group (collaborative) navigation, hyperbolic navigation algorithms, underwater acoustic modem.

Vaulin Yu.V., Dubrovin F.S., Shcherbatyuk A.F., Shcherbatyuk D.A. HYPERBOLIC NAVIGATION SYSTEM FOR PROVISION OF THE GROUP OPERATION OF MARINE ROBOTIC COMPLEXES // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 22–33.

Navigation guidance support of group operations of marine robotic complexes (MRC) assumes simultaneous (in the frames of one navigation cycle) positioning of all the objects of MRC. Widely used long-baseline underwater acoustic navigation system (LBL UANS) is not able to solve this problem, as it works with objects of the MRC sequentially. This paper investigates the problem of navigation guidance support of the MRC objects using a hyperbolic navigation system (HB NS). Two navigation algorithms that implement direct-search and analytical methods for solving difference-rangefinding tasks are studied. The method of implementing HB NS with adaptive configuration was proposed for navigating the MRC objects in the acoustic shadow zone. The designed HB NS has undergone several experiments, including computer modeling of described algorithms and full-scale sea trials of the entire system operation, and thus proved its working capacity and the required accuracy.

Key words: towed surface radiocommunication module, autonomous underwater robot, dynamic model of the tethered system, motion control.

Kostenko V.V., Mokeeva I.G. THE RESEARCH OF STEADY-STATE MODES CHARACTERISTICS, AND DYNAMICS OF TETHERED SYSTEM OF THE AUTONOMOUS UNDERWATER ROBOT WITH TOWED SURFACE RADIOCOMMUNICATION MODULE // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 34–41.

Utilization of the towed surface radiocommunication module (SRM) allows organizing a high-speed communication channel between the control station and autonomous underwater robot/autonomous underwater vehicle (AUR/AUV), as well as significantly simplify its navigation guidance support. Herewith, the disturbances from communication cable effects on AUV and SRM, and heavily influences the motion characteristics of such a tethered system. This paper studies force actions of communication wire on towage and its influence on vehicle motion along standard maneuvering trajectories in steady-state modes using computer modeling. The length of communication cable providing minimal force actions on the vehicle from towing was determined for steady values of submersion depth and movement speed of the AUV. The integrated model of the motion control system of the underwater tethered system was proposed taking into account the dynamic of AUV and communication cable. The kinematic model of SRM behavior was designed to determine its submersion depths and hydrodynamic resistance while being towed. Acquired and demonstrated results of the tethered system motion modeling along standard trajectories typical for search operations allow estimating additional requirements for thrust characteristics of the propulsion/steering unit of the vehicle, as well as the necessary buoyance reserve of the SRM.

Key words: combined receiver unit, flow noises, near filed, noise sustainability.

Kasatkin B.A., Kasatkin S.B. the FEATURES OF THE COMBINED RECEIVER UNIT OPERATION ABOARD UNDERWATER GLIDER // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 42–48.

While operating aboard moving carrier, the receiver system faces a specific problem of reducing self-noises of the carrier, the magnitude of which depends on the type of receiver system and algorithms of signal processing. The present work considers the features of the combined receiver unit operation aboard underwater glider in self-generated flow noises, originated when the glider positioning horizon is changed. The complete description of the energetic structure of the sound field, including 16 informative parameters, is proposed. The list of parameters includes sound pressure squared, components of the complex intensity vector, components of the real curl of an intensity vector, and quadratic components

of the complex vector of the pressure gradient. The theoretical background is supported by the results of the marine trials conducted in the shallow aquatic area. In it, the underwater glider equipped with the combined receiver unit sequentially changed the positioning horizon in the "submerging-emerging" mode. The levels of flow noise on the output of the sound pressure channel and the output of the vector channel are comparatively analyzed for different determinations of informative parameters, characterizing the sound field in the scalar-vector description. The presented estimates of flow noises levels confirm the advantages of a combined receiver unit compared to a hydrophone while operating as a part of the on-board receiver system in a near field on self-generated flow noises.

Key words: Amursky Bay, optically complex waters, bio-optical parameters, light penetration depth, satellite probing, sea color, chlorophyll a, dissolved organic matter, turbidity, MUMM atmospheric correction.

Saljuk P.A., Stepochkin I.E., Zaharkov S.P., Ignat'eva E.S., Jakovleva D.A., Shupilo A.I., Kachur V.A., Nagornyj I.G. THE ANALYSIS OF APPLICABILITY OF SATELLITE DATA OF SEA COLOR IN AMURSKY BAY IN SUMMER-TIME // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 49–55.

The Amursky Bay suffers from the severe anthropogenic impact, so it is important to organize multi-level monitoring for continuous real-time ecological control. This work aimed at performing experimental research focused on solving the following tasks:

- estimation of the effectiveness of satellite probing of sea color in optically complex waters of marine aquatic areas,
- conducting under-satellite underwater experiments and determination of the depth of layers, significantly influencing on forming optical signals recorded from the space.

Solving the stated tasks relies on two oceanographic sections, whereon vertical measurements of bio-optical and hydrological parameters of sea column were performed. In this regard, satellite images of radiometers MODIS-Aqua, MODIS-Terra, VIIRS-NPP with the application of NIR, and MUMM algorithms of atmospheric correction were analyzed. Obtained results demonstrate that in August color of the waters of the Bay is mainly formed in the upper 10 meters layer, which is exposed to rivers run-offs and consists of a large amount of dissolved and suspended matters. The influence of the bottom and macro seaweed should not appear on depths more than 15 meters. For adequate usage of satellite data, it is firmly necessary to use the MUMM algorithm and recommended organizing and automated networks of under-satellite surveys.

Key words: hydrophysical complex, complex low-frequency signal, vertical underwater acoustic antenna, wideband underwater acoustic transducer, internal gravitational waves.

Pivovarov A.A., Samchenko A.N., Shvyrev A.N., Yaroshchuk I.O. A USE OF HYDROPHISICAL RESEARCH COMPLEX IN FULL-SCALE EXPERIMENTS ON THE SHELF OF THE SEA OF JAPAN // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 56–61.

Fall 2019, a full-scale integrated experiment took place on the shelf of the Sea of Japan in Peter the Great Bay. It was aimed at studying the influence of internal waves on the propagation of complex low-frequency signals. Experimental works were performed using novel hydrophysical research complex. It consists of the vertical 8-element receiving antenna, autonomous wideband transmitting station, multi-element thermo-strings, and hydrostatic pressure recorder. Within 24 hours, packets of different signals with linear frequency modulation and phase-shift keying were emitted and recorded with simultaneous measurements of characteristics of the internal waves field along the propagation path. During experiments, the technical parameters of the hydrophysical research complex were verified, and some experience of performing integrated oceanological experiments were obtained. Differences in the usage of linear frequency modulated and phase-shift keyed signals were found. The influence of hydrological interference on underwater acoustic signals propagation typical for the aquatic area was demonstrated.

Key words: underwater surveillance systems, variations of underwater currents, sea disturbance, artificial and natural markers of underwater currents, video processing.

Fischenko V.K., Zimin P.S., Golik A.V., Goncharova A.A. UTILIZATION OF STATIONARY UNDERWATER SURVEILLANCE SYSTEMS FOR the estimation OF UNDERWATER CURRENTS AND SEA DISTURBANCE PARAMETERS // Underwater Investigation and Robotics. 2020. No. 2 (32). P. 62–73.

Stationary systems for underwater video surveillance designed in POI FEB RAS apart from solving tasks of marine biot monitoring in the off-shore strip of Peter the Great Bay can be used for estimating characteristics of sea disturbance and underwater currents. These characteristics are essential both for supplementing the observations of life activities of marine organisms with hydrological existence conditions and by itself, as vital parameters of environmental conditions. This work considers several methods of measuring signals of variations of underwater currents and estimating frequency properties of sea disturbance on its basis. The main idea is to track horizontal movements of light markers driven by underwater currents based on the video analysis. The first part of the article presents examples of the utilization of markers of two types: tennis balls with slightly positive or negative buoyancy mounted on thin thread and propellers mounted on the bottom. It is shown that at a small depth of the camera installation, the frequency properties of the signals of markers horizontal movements are easily reproduced in signals of sea surface disturbance in the range of wind waves, sea swells, seiche oscillations of the sea level with a period from tens of seconds to tens of minutes. The second part of the article considers technologies of measurements based on the utilization of natural markers, such as fields of organic and inorganic suspended matter moved by water streams in front of a camera or submerged vegetation, which inclination angle is changed under the influence of currents. These approaches can be used in the absence of artificial markers or their failure.