SELECTION OF THE OPERATING FREQUENCY OF THE HYDROACOUSTIC SYSTEM FOR REDUCING THE UNDERWATER VEHICLE TO THE DOOR MODULE AND PROPOSALS FOR THE CHOICE OF ITS STRUCTURE

DOI: 10.36724/2072-8735-2021-15-7-55-61

Manuscript received 30 April 2021;
Accepted 28 May 2021

Boris I. Filippov,
Novosibirsk State Technical University, Novosibirsk, Russia,
filippov-boris@rambler.ru

Keywords: *autonomous underwater vehicle, docking module, hardware structure hydroacoustic guidance system*

The proposed work is a continuation (the second part) of the overall work on the development of the structure of the hydroacoustic navigation system (HNST) for bringing the autonomous underwater vehicle (AUV) to the docking module (DM). The first part was published in the previous issue of the magazine.The purpose of this is to develop and study a prototype of the equipment for a short-range high-frequency HNST to ensure the docking of AUV with a carrier. The expediency of constructing the equipment of a high-frequency hydroacoustic system for bringing the AUV to DM in the form of a combined information and navigation system combined on the basis has been substantiated. It can use hydroacoustic navigation systems with short and ultrashort antenna bases; it is proposed to use data signals as navigation signals, which are exchanged between the docking module and the autonomous underwater vehicle based on the results of measuring the mutual navigation characteristics. It is recommended to select the operating frequency in the lower part of the allocated frequency range 100 ÷200 kHz. It should be considered that the accuracy of determining the position of the AUV in the process of alignment can be a variable value: with an increase in the distance to the DM, the errors in estimating the spatial coordinates of the AUV can increase without compromising the functionality of the alignment system. Therefore, in order to select a scenario for the movement of the AUV in the process of alignment, it would be desirable to know the dependence of the errors in estimating its spatial coordinates, admissible when con-trolling the movement of the AUV, on the distance to the DM. In the absence of the indicated dependence, it is possible to take advantage of the somewhat overestimated requirements for the targeting zone for the estimation of the navigation characteristics of the targeting HNST. Then the alignment strategy can be reduced to the choice of the AUV motion scenario, which provides the maximum required accuracy of the estimation of its spatial coordinates in the entire alignment zone. A variant of building an HNST, consisting of unified basic sets of a docking module (BS – DM) and an underwater vehicle (BS - AUV), has been proposed. The basic set of the (BS – AUV) underwater vehicle is similar in structure and function to the basic set of the docking module. Its difference from the (BS-DM) is in the presence of a control unit for the underwater vehicle (CUV), through which signals are exchanged between the (BS - AUV) and the AUV autopilot.

Information about author:
Boris I. Filippov, *Novosibirsk State Technical University, Ph. D. in Technical Scinces, Department of Information Protection, Novosibirsk, Russia*

Для цитирования:
Филиппов Б.И. Выбор рабочей частоты гидроакустической системы приведения подводного аппараты к стыковочному модулю и предложения по выбору её структуры // T-Comm: Телекоммуникации и транспорт. 2021. Том 15. №7. С. 55-61.

For citation:
Filippov B.I. (2021) Selection of the operating frequency of the hydroacoustic system for reducing the underwater vehicle to the door module and proposals for the choice of its structure. *T-Comm*, vol. 15, no.7, pp. 55-61. (*in Russian*)

Introduction

The proposed work is a continuation (of the second part) of the overall work on the development of the structure of the hydroacoustic navigation system (HNST) for bringing the autonomous underwater vehicle (AUV) to the docking module (DM). The first part was published in the previous issue of the magazine.

As previously indicated, the operating frequency of the navigation system is in the range of 100 ÷ 200 *kHz*. When choosing an operating frequency, one should proceed from the fact that suboptimal incoherent receivers of discrete relative phase modulation (DPSM) signals are taken as the basis for constructing equipment for HNST [1]. For reasons of increasing the stability of the equipment to the action of Doppler interference, it is advisable to process and receive data signals directly at the frequency of the carrier wave f_0. In this regard, the frequency of the carrier wave f_0 must be a harmonic of the frequency $1/T_0$, here T_0 – the duration of the symbol, that is, the frequency of the carrier wave must meet the condition: $f_0 = 4k\ [kHz]$, where k is an integer.

Due to the movement of AUV relative to DM with a radial velocity v, the data signal changes the scale of its representation in the time and spectral domains. The symbol duration decreases to T_0', and the average spectrum frequency increases to f_0'

$$T_0' = T_0\left(1 - \frac{v}{c}\right),$$

$$f_0' = f_0\left(1 + \frac{v}{c}\right),$$

where speed c is the speed of sound in water; we accept $c = 1500\ м/с$. Substituting the value of the radial velocity of the AUV relative to the DM $v = 3\ m/c$, we obtain $T_0' = 0{,}998 \cdot T_0$, $f_0' = 1{,}002 \cdot f_0$. The relative change in the time scale of the signal is less than the assumed relative value of the step of correcting the position of the output signals of the clock synchronization system $\delta_k \geq 0{,}005$, and it can be neglected.

The bandwidth ΔF of the data signal transmitted at the rate $V = 4000$ Baud is estimated to be 4000 *Гц*. Since $\Delta F = (f_0' - f_0)$, then with sufficient accuracy for engineering calculations, the spectrum shift can be neglected, leading to a violation of the orthogonality condition between the signal coming from the channel and the reference signals generated in the receiver. The absolute value of the aforementioned shift of the signal spectrum due to the action of the Doppler interference decreases with decreasing its operating frequency. This allows us to conclude that it is preferable to select the operating frequency in the lower part of the selected frequency range 100 ÷ 200 *kHz*.

The influence of the Doppler shift of the signal spectrum must be taken into account when assessing the bandwidth of the receiving path. Based on the signal spectrum width $\Delta F = 4000\ kHz$, the spectrum shift of the signal coming from the channel due to the Doppler effect $(f_0' - f_0) \leq 400\ Hz$, and also taking into account the spread of the parameters of the radio engineering elements used, the bandwidth of the receiving path should be chosen approximately equal to 5 *kHz*.

Problem statement and solution

Presentation of the HNST in the form of a combined information and navigation system allows you to select a signal system that allows you to solve the problem of bringing the AUV to the DM regardless of the type of HNST used, with a short or ultrashort antenna base [2, P. 183].

At the same time, in HNST it is advisable:

– o use as navigation data signals, which are exchanged by AUV and DM based on the results of mutual measurement of navigation characteristics;

– o carry out data exchange between AUV and DM by the method of relative phase modulation with speed $V = 4000$ Baud;

– select the operating frequency in the lower part of the allocated frequency range 100 ÷ 200 *kHz*;

– use he sequence of the header and the data block as the data signal transmitted in the channel;

– a ply a header consisting of a number of repeating starting 15-*bit* M-sequences and their corresponding numbers, transmitted by the correcting +block cyclic code (15,4);

– hange in the header the number of starting 15-*bit* M-sequences and their corresponding numbers, depending on the quality of the channel;

– o transfer the data block using the correcting block cyclic code (224, 200);

– apply div rsity reception in combination with majority decoding of symbols to receive a data block, and then correct errors in the data block using a code, and accompany the data output to the user with a sign of detection by an error code in the block.

On the possibilities of GNSS with a short and ultrashort antenna base

Analyzing and summarizing the results of qualitative and quantitative assessments, in the first approximation, of the navigation characteristics of HNST with a short and ultra-short baseline [3, 4, 5], it is possible to formulate the features of the considered HNST that are most signifion signal. It allows to provide the required estimation error of the specified parameter of the navigation system at the signal-to-noise ratio in the "idealized" (for the channel model used in the calculations) hydroacoustic channel not less than 12-15 *dB* [6-8]. Signal / noise ratios of this order are quite achievable and can accant for the construction of the AUV targeting system, which are reduced to the following.

The use of HNST with a short antenna base makes it possible to obtain in the AUV targeting system the full volume of navigation characteristics (either the Cartesian coordinates of the target object, or its angular coordinates and inclined distance) and, in principle, makes it possible to implement the target zone, limited only by the width of the radiation pattern (RP) of the DM antennas and AUV [3].

Theoretically, when using weakly directional antennas, for some areas of the deep sea, it is quite possible to provide AUV guidance even in a space bounded by a hemisphere, placing the DM in the geometric center of the sphere. However, the practical implementation of such a possibility is associated with the structural and technological difficulties of creating weakly directional antennas as part of the general design of the HNST carrier, especially for the frequency range above 100 *kHz*.

The capabilities of the HNST with a short antenna base in terms of the volume of navigation characteristics necessary to bring the AUV to the DM allow it to be used either as an autonomous navigation system, or to be included in the combined information and navigation guidance system.

To ensure the required resolution of the HNST with a short baseline, it is necessary to implement a subsystem for measuring the propagation time of the navigation signal between the DM and the AUV in the reference area, which allows determining the specified parameter with a sufficiently high accuracy.

The preliminary studies carried out indicate the possibility of technical implementation of such a subsystem for measuring the propagation time of the navigattually be observed even in shallow sea conditions in the presence of surface and bottom scattering [6,7].

The distances between the antennas in HNST with a short baseline allow, in case of insufficient signal / interference ratio in the hydroacoustic channel, to implement in the combined information and navigation system of bringing spatially-separated reception, which ensures the specified reliability of the reception of information transmitted over the hydroacoustic channel.

The use of HNST with an ultrashort base provides the possibility of obtaining in the AUV reference system only the angular coordinates of the reference object, which requires the introduction of equipment into the navigation system to determine the slant distance to the AUV [5]. In this respect, the HNST with an ultrashort base fits well into the combined information and navigation guidance system with the function of determining the slope distance.

Another drawback limiting the use of HNST with an ultrashort base as an autonomous navigation system is the need to introduce a preliminary (rough) estimate of the AUV's spatial position in the targeting zone into the procedure for bringing the operation into account. This requires either the introduction of additional equipment, or the availability of relevant information from other standard navigation aids of the AUV or the DM carrier.

HNST with an ultrashort base with a minimum number of spatial receiving channels, which is equal to five, makes it possible to provide the required error in estimating the angular coordinates of the AUV when the signal / noise ratio in the "idealized" hydroacoustic channel is not less than 3 *dB*, which indicates the possibility of its effective functioning in real hydroacoustic channels.

The capabilities of HNST with a short and ultrashort base for determining the spatial position of the AUV in the targeting zone are largely determined by the following characteristics: RP, amplitude-frequency characteristic (AFC) and phase-frequency characteristic (PFC) and characteristics of hydroacoustic antennas, which, in turn, are closely related to the specific design of antennas in a given frequency range and their placement on appropriate carriers. These issues deserve their own consideration and are beyond the scope of this work.

As part of the task, it is only necessary to note the following. When implementing HNST alignment antennas, consisting of separate elements, one should, if possible, strive to ensure the identity of the characteristics of these elements in order to minimize the errors in the assessment of navigation characteristics associated with the non-identity of the transfer characteristics and the calibration of the receiving paths of the navigation system.

The width of the RP of the elements of the HNST antennas, in the azimuth and elevation planes, has a significant impact on the capabilities of the navigation system. The use of highly directional antennas significantly limits the areas of the target space, and the use of weakly directional antennas can lead to a decrease in the required signal-to-noise ratio in the hydroacoustic channel due to an increase in the level of reverberation noise during surface and bottom scattering. In this regard, it would be preferable to have antennas with weak directivity in the azimuth plane and mid-directionality in the elevation plane.

To combine the positive qualities of HNST with a short base and HNST with an ultrashort base in one system, it is possible to build a targeting system combined on the basis of antennas. There are no restrictions on the implementation of hardware and software for such a targeting system, and the spatial configurations of the antenna modules of HNST with a short antenna base and HNST with an ultrashort base turn out to be fundamentally compatible. The only factor limiting the use of the combined targeting system may be the overall size of the antenna module, which may not fit into the overall design of the HNST carrier. Thus, it is most likely that the installation of the antenna module of the combined guidance system on the DM of various designs will not cause fundamental structural and technological limitations, but its placement on the AUV may turn out to be unacceptable. In this case, the AUV targeting system should be based on a HNST with an ultrashort base, the antenna module of which has a smaller overall dimensions.

AUV alignment strategies

In the process of targeting, the task of ensuring the underwater docking of the AUV with the carrier is being solved. Within the framework of the task, the targeting strategy can be characterized as the choice of the scenario of the AUV movement, which in different areas of the targeting zone (distance from 1 *m* to 300 *m*) would provide the required accuracy of determining its spatial location with the its hydrology.

It should be noted that the accuracy of determining the position of the AUV during the alignment process can be a variable value: with an increase in the distance to the DM, the errors in estimating the spatial coordinates of the AUV can increase without compromising the functionality of the alignment system. Therefore, in order to select the scenario for the movement of the AUV in the process of alignment, it would be desirable to know the dependence of the errors in the estimation of its spatial coordinates admissible when controlling the movement of the AUV on the distance to the DM.

In the absence of the indicated dependence, it is possible to take advantage of the somewhat overestimated requirements for the reduction zone for estimating the errors of the navigation characteristics of HNST. Then the alignment strategy can be reduced to the choice of the AUV motion scenario that provides the maximum required accuracy of the estimation of its spatial coordinates in the entire alignment zone.

For a combined antenna based on a combined information and navigation system, the strategy for bringing the AUV to the DM can be based on the choice of such a scenario for the AUV movement, in which, depending on the section of the targeting zone, navigation characteristics of either GNSS with a short base or characteristics of HNST with an ultrashort base. The trajectory of the AUV is predicted on the basis of the water area profile, based on the conditions for providing in the hydroacoustic channel of the targeting system sufficient for assessing the navigation characteristics of the signal-to-noise ratio, indirectly estimated by the quality of the hydroacoustic channel of the targeting system data exchange [3].

So, in the areas of the far targeting zone, where the probability of the appearance of small signal / noise ratios is the highest, the navigation characteristics of a HNST with an ultrashort base can be used to control the movement of the AUV. As we approach the DM (starting from the middle targeting zone) and at the berthing area, to improve the targeting accuracy, it is more expedient to use the navigation characteristics of HNST with a short base.

Prediction of the trajectories of the AUV, allowing to provide the required resolution of the HNST in the reference zone, is based on the data of measurements of the water area and hydrology profile.

In the conditions of shallow sea water areas, characterized by the presence of sufficiently strong surface and bottom scattering, it is preferable to preferentially horizontal trajectory of the AUV during the alignment process, since it is very difficult to ensure the required accuracy of measuring the elevation angle in the areas of the far alignment zone even when using GNSS with an ultrashort baseline [4, 5].

For deep sea water areas, the trajectory of the AUV in the targeting zone has a much lesser effect on the accuracy of determining the location of the AUV during the targeting process. The boundaries of the targeting zone will depend on the width of the antenna pattern installed on the DM and AUV.

Additionally, it should be noted that, according to preliminary qualitative estimates, the refractive distortions of the navigation signal in the middle and near target zones in most cases turn out to be insignificant and this component of the error in determining the navigation characteristics of the targeting system can be neglected. In the areas of the far target area, in order to meet the requirements of the technical specifications for the accuracy of the assessment of the spatial coordinates of the AUV, it is necessary to take into account the component of the error associated with the refractive distortion of the navigation signal [2, P. 31].

Taking into account the influence of refractive distortions of the navigation signal in the guidance system will lead to an increase in the time for updating the navigation characteristics when controlling the movement of the aircraft. To confirm the feasibility of introducing into the structure of navigation signals processing, the procedure for assessing the errors of refractive distortions, a quantitative assessment of the influence of this error on the accuracy of assessing the navigation characteristics and the tactical capabilities of the targeting system is required.

Such an assessment can be made at the stage of the technical design of a component of the experimental design developments (EDD) in the development of an experimental sample of the equipment of the targeting system and the refinement of its tactical and technical characteristics. The remarks presented in this paper contain information of a systemic nature and can serve as the basis for the development of the general structure and tactical and technical characteristics of the equipment of the high-frequency hydroacoustic targeting system.

Suggestions for choosing the structure of HNST

Above, the expediency of building HNST equipment in the form of a combined information and navigation combined system based on antennas was shown, in which HNST with a short and ultrashort antenna base can be used, and data signals are used as navigation signals, which are exchanged between DM and AUV based on the results of measuring mutual navigation characteristics.

If we assume that the implementation of the HNST is carried out mainly with the use of algorithms for digital processing and signal generation, then one of the possible options for constructing the equipment is associated with the implementation of unified basic sets of the docking module (BS - DM) and the underwater vehicle (BS - AUV) according to the schemes, shown in Figures 1 and 2, respectively.

The(BS – DM) includes: a docking module control panel (DU – DM) D1, a cyclic code decoder (224,200) D2, a majority symbol decoder D3, a channel quality analyzer D4, a D5 calculator, a start sequence extraction unit D6, a time interval measurement unit D7, a data signal transmitter D8, a block of suboptimal DPSM receivers D9, an analog-to-digital converter (ADC) block D10, a transmitter-receiver hydroacoustic antenna D11.

The peculiarity of the proposed scheme is the use of a combined hydroacoustic antenna system based on which a HNST with a short and ultrashort base can be built. As indicated in [3], a minimum of 4 receiving elements should be used in the antenna system to build HNST with a short base. To implement a HNST with an ultrashort base, the antenna system must have 5 receiving elements [4]. Some of these elements (up to four) can be simultaneously used to build HNST with a short baseline. In [4], it was shown that to ensure the required quality of data exchange between the DM and the AUV at the limiting slope distances between them, one should use their five- or, even better, seven-fold diversity reception in combination with majority decoding of the symbols that make up the data block. This is ensured by the addition of one or three additional receiving elements to the antenna system, respectively.

In addition, one transmitting element must be included in the hydroacoustic antenna system, through which the transmitted data signals are emitted. As a result, the transmitter-receiver hydroacoustic antenna module can contain from 6 to 8 receiving elements and one transmitting element. The final composition and design of the module is set by the customer, who is the developer of the transceiving hydroacoustic antenna. The output signals of the receiving elements of the transceiving hydroacoustic antenna module are converted into a sequence of digital samples by means of the D10 ADC unit and fed to the D5 calculator.

At the same time, the sign digits of the indicated digital readings from an odd number of receiving elements of the receiving-transmitting hydroacoustic antenna module (from five or seven), used for organizational reception of the data signal, arrive from the output of the ADC D5 to the block of suboptimal DFM receivers D9. Suboptimal DPSM receivers D9, the corresponding number of sequences of demodulated binary symbols are fed to the inputs of the majority symbol decoder D3 and the block for separating the starting sequences D6.

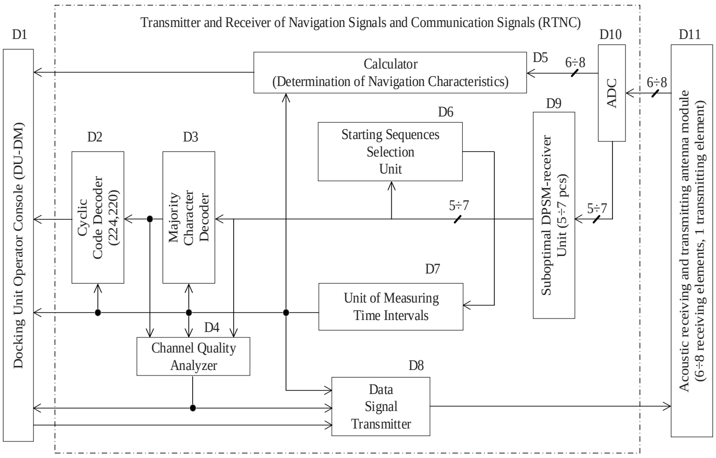

Fig. 1. HNST. Equipment. Block diagram of the basic docking kit module (BS-DM)

As the sequences of demodulated binary symbols of the start sequences are detected in the sequences of the demodulated binary symbols of the start sequences coming from the suboptimal DPSM receiver D9 block, the corresponding "sign" signals from the start sequence selection unit D6 are fed to the input of the time interval measurement unit D7.

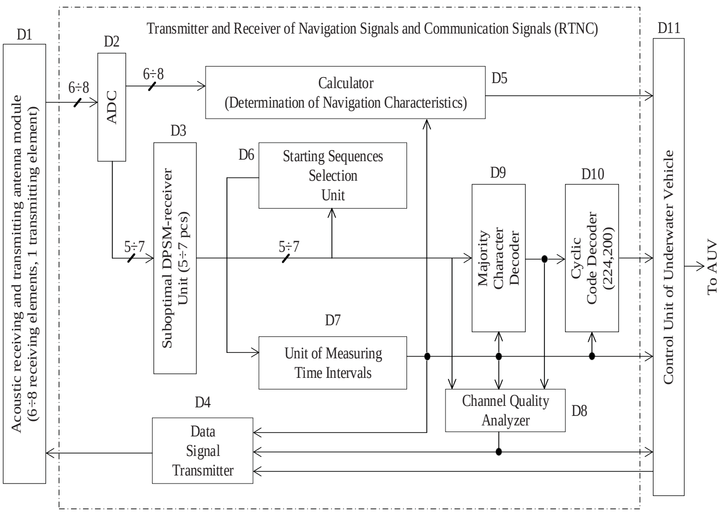

Fig. 2. HNST. Equipment. Block diagram of the basic set of underwater vehicles (BS – AUV)

The time interval measuring unit D7, with its output signals, sets the sequence of operation of the calculator D5, the majority symbol decoder D3, the channel quality analyzer D4, the cyclic code decoder (200,224) D2, the control panel of the docking module D1 and the data signal transmitter D8.

First, when the first of the starting sequences is detected, the D5 calculator starts processing signals from the output of the D11 receiving-transmitting hydroacoustic antenna module according to the HNST program with an ultrashort base. At the end of the header, according to the signal from the D7 time slot measurement unit, the majority symbol decoder D3 and the D4 channel quality analyzer start processing the sequences of demodulated binary symbols coming from the suboptimal DPSM receiver D9 unit. After majority decoding in symbol-by-symbol form, the cyclic code combination (224,200) is fed to the input of the D4 channel quality analyzer and to the input of the cyclic code (224,200) decoder D2, in which it is decoded.

In the channel quality analyzer D4, based on the comparison of the output sequence of the majority symbol decoder D3 with the sequences of demodulated binary symbols from the block of suboptimal DPSK receivers D9, an indirect estimate of the signal-to-noise ratio in the channel is carried out. Signal processing in the decoder of the cyclic code (224,200) D2, in the majority decoder of symbols D3 and in the channel quality analyzer D4 is completed by the signal from the time interval measuring unit D7 at the end of the cyclic code combination (at the time of the end of the data signal).

Simultaneously with the moment of the end of the data signal in the unit for measuring the time intervals D7, the measurement on all channels of receiving the time intervals counted from the moment of the last transmission of the data signal in the direction of the APU ends.

In the D5 calculator, the processing of signals according to the HNST program with an ultrashort base is stopped. The indicated time intervals characterizing the propagation time of the acoustic signal from the AUV to each of the receiving elements of the receiving-transmitting hydroacoustic antenna D11 module are fed to the D5 calculator. Their processing begins according to the HNST program with a short base. After a fixed period of time, sufficient for the execution of the HNST program with a short base, according to the signal from the time intervals measuring unit D7, the results of determining the navigation characteristics of the AUV from the calculator D5 together with the data block decoded in the decoder of the cyclic code (224,200) D2, obtained from the AUV, and also with the estimate of the signal-to-noise ratio in the channel, obtained in the channel quality analyzer D4, are transmitted to the control panel of the docking module D1, where they are displayed and documented in the appropriate form. At the same time, in the transmitter of the data signal D8, on the basis of the AUV navigation characteristics determined in the D5 calculator, and transmitted through the (DU-DM), a data signal is generated to be transmitted to the AUV. The header length (the number of retransmissions of the start sequences in its composition) is set based on the signal-to-noise ratio estimate obtained in the D4 channel quality analyzer.

Depending on the chosen strategy of bringing the AUV, the operator can enter the necessary correction as part of the data block to be transferred to the AUV.

To ensure the measurement of the propagation time of the navigation signal between the DM and the AUV, between the AUV and the DM, the data signal is transmitted by the D8 transmitter according to the signal from the D7 time interval measurement unit after a fixed time interval after receiving the data signal from the AUV. After that, the (BS – DM) again switches to the mode of receiving and processing signals coming from the channel.

The basic set of the underwater vehicle (BS – AUV) is similar in structure and function to the basic set of the docking module. Its difference from the (BS-DM) is in the underwater vehicle control unit (DU-DM) D11, through which signals are exchanged between the (BS – AUV) and the APU autopilot. Otherwise, the purpose and interaction of the (BS – AUV) components coincides with the purpose and sequence of actions of the (BS – DM) components.

Conclusion

1. The effect of the Doppler shift of the signal spectrum must be taken into account when assessing the bandwidth of the receiving path. Based on the signal spectrum width $\Delta F = 4000\ kHz$, the spectrum shift of the signal coming from the channel due to the Doppler effect $(f_0^{'} - f_0) \leq 400\ Hz$, and also taking into account the spread of the parameters of the radio engineering elements used, the bandwidth of the receiving path should be chosen approximately equal to 5 *kHz*.

2. When developing the structure of the AGSP, it is advisable:

– to use as navigation data signals, which are exchanged by AUV and DM based on the results of mutual measurement of navigation characteristics;

– to carry out data exchange between AUV and DM by the method of relative phase modulation with speed $V = 4000$ Baud;

– select the operating frequency f_0 in the lower part of the allocated frequency range 100÷200 *kHz*;

3. A variant of the HNST construction is proposed, consisting of unified basic sets of the docking module (BS – DM) and an underwater vehicle (BS – AUV). The basic set of the (BS – AUV) underwater vehicle is similar in structure and function to the basic set of the docking module. Its difference from the (BS – DM) is in the presence of a control unit for the underwater vehicle (DU – DM), through which signals are exchanged between the (BS – AUV) and the (DU – DM) autopilot.

References

1. B.I. Filippov, A.O. Kozhaeva (2019) Determination of the slope distance in the equipment of the high-frequency hydroacoustic system for bringing the underwater vehicle to the docking module. *Radiotekhnika*. Vol. 83, No. 3. P. 84-95.

2. B.I. Filippov (2019) Digital transmission of information in hydroacoustic telemetry systems. Saratov: IPR Media. 290 p.

3. B.I. Filippov (2019) Architecture of a short-base hydroacoustic navigation system for bringing the underwater vehicle to the docking module. *Mechatronics, automation, control*. Vol. 20, No. 3. P. 152-161.

4. B.I. Filippov (2020) Construction of a hydroacoustic navigation system with an ultrashort base for bringing the underwater vehicle to the docking module. *T-Comm*. Vol. 14, No. 7. P. 20-28.

5. B.I. Filippov (2021) (Determination of the characteristics of bringing the underwater autonomous vehicle to the docking module for the GNS with an ultrashort base. *T-Comm*. Vol. 15, No. 2. P. 11-19.

6. B.I. Filippov (2018) Quantitative and qualitative differences in the characteristics of radio and hydroacoustic communication channels. *Vestnik RGRTU*. No. 1 (63). P. 49-58.

7. G.I. Krivolapov, A.A. Makarov, N.I. Postnikov., G.A. Chernetsky (1988) Some test results of AGAS for control and diagnostics of DSS. In the book. Methodology and technique of seismoacoustic and vibroseismic studies in water areas Coll. scientific. works by ed. Dobrinsky V.I. Novosibirsk, Computing Center of the Siberian Branch of the USSR Academy of Sciences. P. 17-25.

8. V.B. Mitko, A.P. Evtyunov, S.E. Gushchin (1982) Hydroacoustic communication and observation equipment. L.: Sudostroenie, 200 p.

ВЫБОР РАБОЧЕЙ ЧАСТОТЫ ГИДРОАКУСТИЧЕСКОЙ СИСТЕМЫ ПРИВЕДЕНИЯ ПОДВОДНОГО АППАРАТЫ К СТЫКОВОЧНОМУ МОДУЛЮ И ПРЕДЛОЖЕНИЯ ПО ВЫБОРУ ЕЁ СТРУКТУРЫ

Филиппов Борис Иванович, *Новосибирский государственный технический университет, г. Новосибирск,* ***filippov-boris@rambler.ru***

Аннотация

Целью работы является разработка и исследование опытного образца аппа-ратуры высокочастотной гидроакустической навигационной системы при-ведения (ГНСП) ближнего действия для обеспечения стыковки автономного подводного аппарата (АПА) с носителем. Обоснована целесообразность построения аппаратуры высокочастотной гидроакустической системы приведения АПА к стыковочному модулю (СМ) в виде совмещенной информационно-навигационной комбинированной по базе системы. В ней могут применяться гидроакустические навигационные системы с короткой и ультракороткой базой антенн; в качестве навигационных предложено использовать сигналы данных, которыми обмениваются стыковочный модуль и автономный подводный аппарат по результатам измерения взаимных навигационных характеристик. Выбирать рабочую частоту f_0 рекомендуется в нижней части выделенной частотного диапазона 100 ÷ 200 кГц. Следует считать, что точность определения местоположения АПА в процессе приведения может быть величиной переменной: с увеличением расстояния до СМ погрешности оценки пространственных координат АПА могут увеличиваться без ущерба функциональным возможностям системы приведения. Поэтому для выбора сценария движения АПА в процессе приведения желательно было бы знать зависимость допустимых при управлении движением АПА погрешностей оценки его пространственных координат от расстояния до СМ. При отсутствии указанной зависимости можно воспользоваться несколько завышенными для зоны приведения требованиями по оценке погрешностей навигационных характеристик ГНСП. Тогда стратегия приведения может быть сведена к выбору сценария движения АПА, обеспечивающего максимальную требуемую точность оценки его пространственных координат во всей зоне приведения. Предложен вариант построения ГНСП, состоящий из унифицированных базовых комплектов стыковочного модуля (БК-СМ) и подводного аппарата (БК-АПА). Базовый комплект подводного аппарата (БК-АПА) по своей структуре и функционированию аналогичен базовому комплекту стыковочного модуля. Его отличие от (БК-СМ) заключается в наличии блока управления подводного аппарата (БУП), через который осуществляется обмен сигналами между (БК-АП) и автопилотом АПА.

Ключевые слова: *автономный подводный аппарат, стыковочный модуль, структура аппара-туры гидроакустической системы приведения.*

Литература

1. *Филиппов Б.И., Кожаева А.О.* Определение наклонного расстояния в аппаратуре высокочастотной гидроакустической системе приведения подводного аппарата к стыковочному модулю // Радиотехника. 2019. Т. 83. № 3. С 84-95.
2. *Филиппов Б.И.* Цифровая передача информации в системах гидроакустической телеметрии. Саратов: Ай Пи Ар Медиа, 2019. 290 с.
3. *Филиппов Б.И.* Архитектура гидроакустической навигационной системы с короткой базой для приведения подводного аппарата к стыковочному модулю // Мехатроника, автоматизация, управление. 2019. Т. 20. № 3. С. 152-161.
4. *Филиппов Б.И.* Построение гидроакустической навигационной системы с ультракороткой базой для приведения подводного аппарата к стыковочному модулю // T-Comm: Телекоммуникации и транспорт. 2020.Т. 14. № 7. С. 20-28.
5. *Филиппов Б.И.* Определение характеристик приведения подводного авто-номного аппарата к стыковочному модулю для ГНС с ультрокороткой базой // T-Comm: Телекоммуникации и транспорт. 2021. Т. 15.№ 2. С. 11-19.
6. *Филиппов Б.И.* Количественные и качественные различия характеристик радио и гидроакустического каналов связи // Вестник РГРТУ. 2018. № 1(63). С. 49- 58.
7. *Криволапов Г.И., Макаров А.А., Постников Н.И., Чернецкий Г.А.* Некото-рые результаты испытаний АГАС для управления и диагностики ДСС // В кн. Методика и техника сейсмоакустических и вибросейсмических исследований на акваториях // Сб. научн. трудов по ред. Добринского В.И. Новосибирск, ВЦ СО АН СССР. 1988. С.17-25.
8. *Митько В.Б., Евтюнов А.П., Гущин С.Е.* Гидроакустические средства связи и наблюдения. Л.: Судостроение, 1982. 200 с.

Информация об авторе:

Филиппов Борис Иванович, *Новосибирский государственный технический университет, к.т.н., доцент, доцент кафедры Защиты информации, г. Новосибиск, Россия*