The research of temperature instability influence of optic communication line on the phase difference a deep-sea direction finder.

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Abstract. The article of the methods for coordinates determination of the object coordinates are reviewed. The advantages of a passive method with the using of the direction finder are noted. The problems arising from the transmission of signals in the direction finder method are determined. The construction for the signal transmission of the fiber optic communication line is presented. It is established that the greatest influence on the error in determining the coordinates of the object by direction finder has a phase shift in the optical fiber during a change the temperature. The chart of the phase shift at the temperature for various cases of optical fiber placement are investigated. The obtained data of the experimental investigations are presented.

1. Introduction
At this point of time there is a great number of methods definition the location (coordinates) of different objects [1-8]. These methods need to be qualified in three areas (on work principle of the station): active, passive and combined [8-13]. Combined radar methods are used in space systems to determine the coordinates of an object on the Earth's surface or in the solar system. Active methods are used in radars placed on moving objects [1, 9, 14-19]. The passive methods in some cases are the only true solution for determining the object position [3, 7, 8, 10, 12, 20-22]. This led to the fact that many of them were created using different physical phenomena, for example, nuclear magnetic resonance, polarization of optical laser radiation and acoustics [7, 8, 10, 13, 22-30]. The expediency of their application is determined by the tasks being solved. The greatest difficulties arise when using these methods for the determination the radio emission sources of the air objects or underwater object. Especially in difficult climatic conditions and in the presence of interference.

One solution to this task involves the made of direction finders [31, 32]. The most accurate among the passive methods of direction finding are the amplitude and amplitude-phase. For ensure high accuracy in phase direction finding method need to create the large base between receiving antennas (hundreds of meters). In the case of phase direction finding, equipment for receiving and processing information to eliminate additional interference must be placed at a large (more than 100 m) distance from the antennas.

In most cases, the receiving antennas are detected the weak signals against the background of noise from radio sources. Therefore, it is very important during transmitting these signals from the antenna to the processing device to preserve information without distortions. Any distortion or reduction in the signal-to-noise ratio will increase the error in the object coordinates determining. To save information during its transmission in direction finders, we suggest to use the fiber-optic communication lines.
Using the FOCLs is a solution to the problem of large signal losses during the transmission of information that appear when using microwave cables. The main negative factor for the use of FOCL is the temperature. In the transmitted optical signal the change of temperature leads to a phase shift (foray) \( \delta \phi \). These processes cause changes in the temperature of the optical fiber. A change in temperature leads to an additional phase shift \( \delta \phi \) in the optical fiber. If the value of \( \delta \phi \) has increased significantly, then difficulties arise in determining the coordinates of the object (phase-time and amplitude-phase methods of direction finding). Therefore, for each design of radio direction finder it is necessary to investigate the effect of temperature on phase shifts during transmission of the signal off the microwave in the optical line.

2. Experimental research of temperature difference influence on the phase difference in the optical channel and discussion.

There are some peculiarities in the operation of a direction finder in a deep-water station. We took these features into account in the design of the developed experimental setup. Basically, these features are associated with the position of the direction finder under water. In most cases, it is impossible to provide thermal insulation of the optical fiber in the direction finder.

For the studies to be complete, it is necessary to investigate two cases of temperature stability of the phase difference in the channels. Microwave signals are transmitted in these channels. Consider these two cases. In the first case, only temperature changes in the FOCL were considered. The studies were carried out by varying the temperature of the entire optoelectronic path. In the second case, temperature changes in equipment for signal transmission from the microwave to the optical range were considered. To implement these studies, an experimental setup was developed (Fig. 1).

An important characteristic of FOCL is its own noise level. To study it, we used a vector network analyzer (Rohde & Schwarz ZVA 40). For this, the following mode is implemented. The signal (power of 0 dBm) is fed to the microwave modulator and transmitter from the vector network analyzer. It should be noted that the design of the experimental setup makes it possible to study the dependence of the intrinsic noise of the entire optoelectronic path on temperature.

With the use of the experimental setup, we studied the effect of temperature on the phase difference of the two optical channels. The developed experimental setup has great functional capabilities; it is possible to study the change in its own noise from temperature for the entire optoelectronic path. Also, for different temperatures, it is possible to study the dependence of the transmission coefficient of the FOCL on the frequency of the microwave signal. One variant of such studies is shown in Fig. 2. This
is the dependence of the phase incursion of the microwave signal $\delta \phi$ in the optical channels on the temperature change for two versions.

![Graph 1](image1.png)

**Figure 2.** Dependence of phase incursion on time. Graph 1 and 2 correspond to the following temperature changes from 284 K to 294 K: 1 - the temperature of only the fiber optic link changes, 2 - the temperature of the entire equipment changes.

Analysis of the results shows that the foray $\delta \phi$ for each of the channels does not significantly differ from each other, if the FOCL is placed side by side in a single retractable probe. The temperature difference in different FOCL must not exceed 0.2 K in the finder in a few hours.

We have investigated the dependence of the change in the phase difference $\Delta \phi$ between the signals in the photodetectors. These signals have traveled different distances under different conditions in optical communication channels, after passing through optical communication channels. Temperature changes in this experiment correspond to the conditions of the experiment carried out earlier (Fig. 2).

![Graph 2](image2.png)

**Figure 3.** Change with increasing temperature $T$ of phase difference $\Delta \phi$ of optical signals in time $t$. After cooling, only FOCL was heated - dependence 1. After cooling, all equipment of the optoelectronic path was heated - dependence 2.

In direction finding systems, to ensure the determination of the position of coordinates with an error of no more than 2%, the maximum permissible change in $\Delta \phi$ should be no more than 12 degrees. Our results show that when only the fiber-optic communication line is cooled, the phase difference $\Delta \phi$ changes within 8 degrees. When the entire equipment is cooled, the change in $\Delta \phi$ increases to 11
degrees. The critical value of 12 degrees is not reached. It should be noted that different types of optical transmitting and receiving modules were used in the study in communication channels. If the equipment is used in channels of the same type, the change in phase difference $\Delta \phi$ will be less.

3. Conclusion
Prolonged temperature changes $T$ with a coarse bearing (18 GHz band) do not lead to more than 12 degrees between channels. With decreasing frequency the phase difference is reduced accordingly. The resulting phase difference is acceptable for rough direction finding system that performs instant radio review space.

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