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IMPROVING THE EFFICIENCY OF SHIP RADAR SYSTEMS FUNCTIONING

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Shipborne radar polarization complexes (SRPC) are remote means that, using electromagnetic waves, ensure the safety of navigation in difficult atmospheric conditions using the information contained in the parameters of the radar signal, while [1-3]:

- amplitude and phase parameters of electromagnetic fields form video signals about navigation objects of radar observation on the indicators of the SRPK;
- when the navigation object is in the zone of atmospheric formation, a total video signal is formed on the indicators of the SRPK, from which it is necessary to select the video signal of the navigation object [1-5];
- the main the operational task of the SRPK is the navigation support of ships along the trajectory of their movement.

When solving this problem, it is necessary to ensure not only the requirements for the potential and informational capabilities of the SRPK, but also for the synthesis of algorithms for detecting and distinguishing signals by their polarization with

When the navigation object is in the zone of hazardous atmospheric formation (heavy showers, hail, snowfall, fog), the SRPK operating at one of the wavelengths used, according to their technical characteristics, cannot carry out polarization selection of the echo signal of the navigation object from the total echo signal of the navigation object - atmospheric formation (complex object) [6].

To solve the posed problem of polarization selection, four polarizations of an electromagnetic wave for radiation were used and an all-polarized antenna of the ship's polarization radar complex received an echo signal of any polarization with measurement of its energy parameters represented by the actual Stokes parameters. The echo signal of a complex object S_{ref} will be partially polarized, and the Stokes parameters S_{1ref} , S_{2ref} , S_{3ref} , S_{4ref} , allow determining the degree of its polarization at the location of the SRPK antenna only from the measured intensities. The Stokes parameters of a partially polarized wave can be grouped using a vector represented in matrix form [7-8]:

$$\left[S_{ref}\right]=\begin{bmatrix} S_{1ref} \\ S_{2ref} \\ S_{3ref} \\ S_{4ref} \end{bmatrix}, \tag{1}$$

where

$$\left.\begin{aligned} S_{1ref} &= \bar{E}^2_{xref}+\bar{E}^2_{yref}, \\ S_{2ref} &= \bar{E}^2_{xref}-\bar{E}^2_{yref}, \\ S_{3ref} &= \bar{E}^2_{x'ref}+\bar{E}^2_{y'ref}, \\ S_{4ref} &= \bar{E}^2_{Rref}+\bar{E}^2_{Lref}. \end{aligned}\right\}, \tag{2}$$

The first Stokes parameter S_{1ref} represents the total intensity of the echo of a partially polarized wave of a complex object and consists of the intensity of the fully polarized part of the echo S_{1refP} and the intensity of the unpolarized part of the echo S_{1refNP}.

The second Stokes parameter S_{2ref} indicates *the predominance* in the echo signal of a complex object of an electromagnetic wave of linear horizontal polarization $S_{2refLLHP}$.

The third Stokes parameter S_{3ref} indicates *the predominance* of an electromagnetic wave of linear polarization in the echo signal of a complex object with an inclination of the electric vector of the wave at an angle of 45° i.e. $S_{3refLP45^o}$.

The fourth Stokes parameter S_{4ref} indicates *the predominance* in the echo of a complex object of an electromagnetic wave of circular polarization of the right direction of rotation of the electric vector $S_{4refCPR}$ or $S_{4refCPL}$.

Since the polarization parameters of an electromagnetic wave are determined only by the amplitude-phase relationships of its components and are stored at the output of the all-polarized antenna of the SRPK when receiving a partially polarized wave, taking into account its decomposition into two polarization-orthogonal components with subsequent amplification and transformation of each of these components in its channel, then Stokes parameters can be represented in terms of the amplitudes and phases of the orthogonal components of the electromagnetic wave in the following form:

$$\begin{aligned} S_{1ref} &= E^2_x + E^2_y, \\ S_{2ref} &= E^2_x - E^2_y, \\ S_{3ref} &= 2E_x E_y \cos\Phi_{xy}, \\ S_{4ref} &= 2E_x E_y \sin\Phi_{xy}, \end{aligned} \tag{3}$$

where $\Phi_{xy} = \varphi_x - \varphi_y$.

Relations (3) make it possible to determine the Stokes polarization parameters of the echo signal of a complex object in any polarization basis, taking into account the known projections of the electromagnetic wave on the axis of the Cartesian coordinate system of this basis. The SRPK all-polarization antenna receives an electromagnetic wave of any polarization completely without polarization losses by converting two components of the electromagnetic wave at the output of the polarization separator (selector) into an electrical signal at once, the parameters of its polarization in the radiation mode and in the receiving mode are the same.

The process of polarization selection of the echo signal of the navigation object located in the zone of atmospheric formation (precipitation of the liquid and solid phases) is based on the difference in the degree of polarization of the echo signal of the navigation object and the atmospheric formation and consists of two stages.

At the first stage, a complex object of radar observation by an all-polarization antenna with controlled polarization SRPK is successively irradiated with electromagnetic waves of four polarizations - three linear and one circular (Fig. 1).

At the second stage, the echo signals of a complex object of a partially polarized electromagnetic wave are received by the all-polarization antenna *9* and through the polarization separator *6*, the switch of the receiving channels *11*, the receiving devices *13*, *14* are fed to the device *15* for obtaining Stokes parameters. Stokes parameters S_1, S_2 , S_3 , S_4 in device *16* form the degree of polarization of the echo signal of the navigation object and the degree of polarization of the echo signal of atmospheric formation, according to the values of which, on the SRPC indicator or on the computer display, an echo signal of only the navigation object or echo is observed -signal of atmospheric formation only [10].

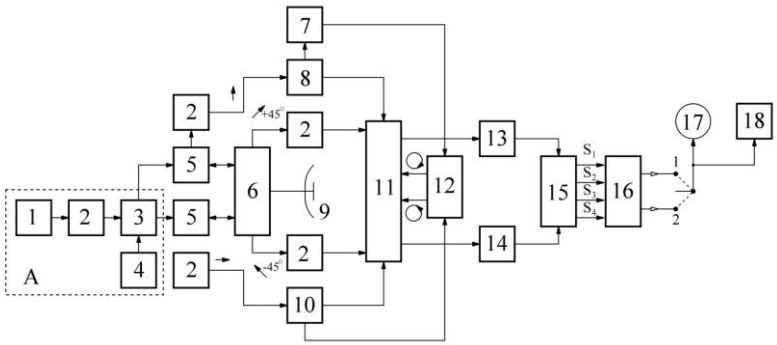

Fig. 1. Functional diagram of the polarization selection of the echo signal of the navigation object located in the zone of hazardous atmospheric formation according to the values of the degree of polarization of the electromagnetic wave

1 - microwave generator; 2 - circulators; 3,4 - device for generating an electromagnetic wave of a certain polarization for radiation, 5 - antenna switches, 6 - polarization separator; 7,8,10,12 - devices for receiving an electromagnetic wave of circular polarization in the receiving mode; 9 - all-polarized antenna; 11 - switch of receiving channels; 13, 14 - linear receiving channels, 15 - device for obtaining Stokes polarization parameters; 16 - device for obtaining the degree of polarization of the echo signal of the navigation object and atmospheric formation; 17.18 - indicator and display of the SRPK computer.

The presented results indicate the possibility of increasing the efficiency of the operation of ship radar systems using the difference in the degree of polarization of echo signals of objects when they are sequentially irradiated with electromagnetic waves of certain polarizations. According to the obtained algorithm, polarization selection is carried out on any of the four polarizations of the emitted wave or only on one of them, depending on the intensity of the process in the atmospheric formation.

The presented method of polarization selection of navigation objects located in the zone of atmospheric formations, using in as an informative radar parameter of the degree of polarization of an electromagnetic wave, it is implemented according to a special program of the ship's radar polarization complex on the presented functional diagram.

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