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The Use of Modern Communications Technology to Ensure the Safe Navigability of the River Estuaries of the Arctic Basin

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ABSTRACT

The constructive decisions allowing to count range of an area of coverage of the modern telecommunication systems are considered in the article. These systems functioning in VHF range are intended for safety of navigation in coastal zone and estuarial areas of rivers of the Arctic basin. The specified decisions allow to find solutions for the VHF range taking into account the actual parameters of transceiver equipment. Moreover influence of the blocking land relief, and also relocation of the ship transponder relative to the base station of Automatic identification system (AIS) are possible to take into consideration. The results of coverage calculations of such systems for the estuarial area of river of the Arctic basin are given in the final part.

KEY WORDS: Estuarial area of river of the Arctic basin; Automatic identification system (AIS); Modern telecommunication technologies; blocking relief; Relative movement of the ship transponder.

FEATURES OF PROVIDING OF SAFE NAVIGABLE CONDITIONS ON ESTUARIAL AREAS OF RIVERS OF THE ARCTIC BASIN

Creating and maintaining of safe navigational conditions in the estuarial areas of the Arctic rivers of the Russian Federation to ensure the timely transportation of cargoes on the rivers of the Arctic basin with access to the Northern Sea Route (Pastusiak, 2016) is a very important and urgent task, because the transport infrastructure in the region is still undeveloped and water transport remains uncontested. This problem is particularly acute in the conditions of intensification of oil and gas mining in the region of the West Siberian Plain and the Arctic shelf, as well as increasing of exploitation of mineral resources of the Republic of Sakha (Yakutia).

The main problem to ensure the navigable depth on the estuarial areas is shallow water on estuarial bars. For maintenance of navigable depths on bar areas it is required to produce annual dredging works, volume of which is estimated in millions of cubic meters of soil. This significant amount of dredging must be produced in a short time, because for a short period the Arctic navigation is required not only to prepare safe navigable waterway, but also provide a significant amount of cargo transportation.

The systematic underfunding of dredging works and the lack of sufficient replenishment of vessels of technical fleet which are decommissioned because of physical and mental deterioration has led to the fact that the depth on estuarial bars decreased significantly, almost reaching their natural values, currently not allowing the vessels of "river-sea" type to pass freely. As a result, ship owners have to bear substantial losses because of downtime of vessels waiting at anchor close to shore line or rising of water levels from the effect of wind surges.

Modernization and acquisition of additional dredging technique, implantation of automated systems for monitoring and control of the technical and auxiliary fleet (ASC TAF) and monitoring of navigation means (SM NM) (Park, et al., 2009) are required in such circumstances to recover the lost dimensions of the ship moves on estuarial areas for the passage of large vessels and qualitatively new navigation and hydrographic support of navigation. Such automated systems based on the use of global navigation systems (GNSS) GLONASS / GPS (Bruyninx, 2006 and Soler, 2004) and modern transceiver systems will allow the technical and auxiliary fleet to carry out their tasks more efficiently and expeditiously. It is necessary to equip the technical fleet by the modern navigation and communication equipment, including electronic chart display and information system (ECDIS) with the possibility of imposing the radar picture on the ECDIS. Under certain conditions it allows to perform track work in conditions of reduced visibility. Equipment of floating beacons and land marks by monitoring system of navigation means in combination with implementation of automated systems of statement of floating navigation beacons will give the chance to reduce operating costs on the fleet. The implementation of the differential mode of GNSS GLONASS, AIS (The British Standards Institution, 2017) and communication systems, modernization of communication systems will accurately track and manage the vessels.

Naturally, the harmonious functioning of these areas of improvement of monitoring and increase of work efficiency of technical and auxiliary fleet is only possible in the structural framework of such ergatic system as ASC TAF which complements the well-known hierarchical infocommunication triad "Corporate river information system (CRIS) - River Information Services (RIS) – vessel traffic service (VTS)".

At the same time it is necessary to consider that before making decision on quantity and location of the base stations (BS) of AIS the carrying out serious scientific and engineering researches is necessary for determination of their topology and range of their action, taking into account architecture and methods of creation of the modern automated networks of safety and communication.

The task of optimization of zones and radius of action of BS AIS defining, eventually, architectonic, and also technological features of their construction is very important for development of topological structure of AIS.

Already created general approach to the solution of task of optimization is based on use of stochastic models of information channels considering the probabilistic nature of three main groups of the facts influencing fidelity of messages transmission.

DISTRIBUTION OF VHF RADIO WAVES TAKING INTO ACCOUNT PARAMETERS OF TRANSCEIVER TRACTS OF APPARATUS

The signals of VHF range used in AIS (Nelson, et al., 2011) can be generally presented as amplitude coefficient of transfer of information channel μ, which is Gaussian independent random variable with mean values m_c and m_s, and also dispersions σ_c^2 and σ_s^2 of orthogonal components.

The one-dimensional density of distribution of transfer coefficient μ(*t*), depending on these four parameters, had received the name of four-parameter distribution

$$W(\mu)=\frac{\mu}{\sigma_c\sigma_s}\exp\left(\frac{\mu^2-m_s^2}{2\sigma_s}-\frac{m_c^2}{2\sigma_c^2}\right)\sum_{k=0}^{\infty}\frac{H_{2k}^{(\alpha)}}{(2k)!!2^k}\mu^k\left(\frac{\sigma_s}{m_s}\right)^k\left(\frac{1}{\sigma_c^2}-\frac{1}{\sigma_s^2}\right)^k I_k\left(\frac{\mu m_s}{\sigma_s^2}\right), \quad (1)$$

where

$$\sigma_c^2\le\sigma_s^2;\ \frac{\sigma_c^2}{\sigma_s^2}<1;\quad \alpha=\frac{m_s}{\sqrt{2\sigma_s^2}\sqrt{\frac{1}{\sigma_c^2}-\frac{1}{\sigma_s^2}}}, \quad (2)$$

H_{2k}(.) – Hermite polynomials of degree 2*k* (Society of Photo-Optical Instrumentation Engineers (SPIE), 2011).

I_k(.) – modified Bessel function of the first kind of order *k* (Balogh, 1966).

At certain phasing of regular component μ_p of signal the following takes place

$m_s=0;\ \mu_p=m_c$ (3)

Then three-parameter Beckmann distribution follows from (1):

$$W(\gamma)=\frac{\mu}{\sigma_c\sigma_s}\exp\left(-\frac{\mu^2\mu_p^2}{2\sigma_c^2}\right)\sum_{k=0}^{\infty}\frac{(2k-1)!!\left(\sigma_s^2-\sigma_c^2\right)^k}{k!2^k\cdot\sigma_s^{2k}\cdot\mu_p^k}\cdot I_k\left(\frac{\mu\,\mu_p}{\sigma_c^2}\right).$$

(4)

At symmetry of information channel on dispersions of quadrature components when the following condition is satisfied:

$$\sigma_c^2=\sigma_s^2=\sigma^2$$

(5)

Rice-Rayleigh distribution (Donato, et al., 1967) or generalized Rayleigh distribution (Raqab, et al., 2011) which are very extended in practice follow:

$$W(\gamma)=\frac{\mu}{\sigma^2}\exp\left(-\frac{\mu^2+\mu_p^2}{2\sigma_c^2}\right)I_k\left(\frac{\mu\,\mu_p}{\sigma^2}\right). \quad (6)$$

In the absence of regular component of signal ($\mu_r=0$) the Rayleigh distributions for the coefficient of transfer of information channel follows:

$$W(\gamma)=\frac{\mu}{\sigma^2}\exp\left(\frac{\mu^2}{2\sigma^2}\right). \qquad (7)$$

In the absence of random changes of quadrature signal components when $\sigma^2 \to 0$ and $\mu = \mu_p$ it is necessary to use model of the channel with constant parameters.

CHANGE OF THE BLOCKING RELIEF BETWEEN THE BS AIS AND THE SHIP TRANSPONDER (ST) AIS

The models for description of analytical probable dependences of relief heights can be used for taking into account of the influence of the blocking relief between BS AIS and ST AIS.

The normal (Gaussian) law of distribution of the relief heights is widely used in case of approximation of various reliefs by methods of mathematical statistics.

$$W(H)=\frac{1}{\sqrt{2\pi}\sigma_H}\cdot\exp\left[-\frac{(H-m_H)^2}{2\sigma_H^2}\right], \qquad (8)$$

where m_H и σ_H^2 – mean value and dispersion of relief of the route between correspondents.

For the law of the even area it is possible to use the following ratio with a one-dimensional probability density

$$W(H)=\frac{1}{(H_{\max}-H_{\min})},\ H_{\min}\le H\le H_{\max}, \qquad (9)$$

The following expression is used for exponential distribution law :

$$W(H)=\alpha\, e^{-\alpha H}\ H\ge 0, \qquad (10)$$

where α– parameter of heights distribution.

PROCESS OF MOVEMENT OF THE ST AIS RELATIVE TO THE BS AIS

Random distances R between the vessel (ST AIS) and the shore (BS AIS) station have significant effect on fidelity of messages transmission in the information channels of AIS.

For the description of such distances it is possible to use, at first, Maxwell's law with one-dimensional probability density:

$$W(R)=\sqrt{\frac{2R^2}{\pi\sigma^3}}\exp\left(-\frac{R^2}{2\sigma^3}\right),\ R\ge 0, \qquad (11)$$

where $\sigma^2=\pi/8R_{av}^2$, R_{av} – the average value of R.

Secondly, the models on the basis of the Rayleigh law:

$$W(R)=\frac{R}{\sigma^2}\exp\left(-\frac{R^2}{2\sigma^2}\right), R\ge 0, \qquad (12)$$

where $\sigma^2 = \frac{2}{\pi} R_{av}^2$,

In case the static data on movement of vessels in transport process are absent, then the uniform law is used:

$$W(R) = \frac{1}{R_{\max} - R_{\min}}, \; R_{\min} \le R \le R_{\max} \tag{13}$$

Also the consideration of electromagnetic hindrances influence is very important, however it doesn't keep within a framework of the current article and demands separate consideration.

CONCLUSIONS

The technique offered in the article allows to model areas of coverage of the modern telecommunication systems functioning in VHF range, for example AIS which is intended for safety of navigation in estuarial areas of rivers of the polar basin. The result of such simulation for the estuarial area of the Yana river is presented in the figure 1. Use of expressions 1 – 13 has allowed to choose the quasioptimum place for the installation of BS AIS. In this case the installation of BS AIS is supposed on the Yuedey cape (0th kilometer).

The installation of BS AIS on the Yuedey cape allows to provide by the telecommunication field of AIS the access to the estuary of the Yana river on remoteness more than 20 kilometers from the coastal line with probability of reception of discrete messages 10^{-3}.

A choice of the installation of BS AIS had been made taking into account, at first, quantitative estimates of range of actions of BS AIS received taking into account the blocking relief and the vessel movement relatively BS AIS, secondly, taking into account existence of elements of infrastructure necessary for the installation of BS of AIS. In case of placement of BS of AIS on the Yuedey cape the automated control of movement of the vessels equipped with the AIS equipment will be possible not only during passing all site of shallow estuarial bar from the receiving buoy to the Yuedey cape, but also to the river port of Nizhneyansk. It should be noted that in certain cases for estuarial areas of the Arctic rivers the impact of industrial noises on the coverage area of BS of AIS is possible not consider in connection with rather low intensity or even lack of the specified class of noises.

As the conclusion it should be noted that the offered technique can be also used rather successfully for other rivers of the Arctic region.

Figure 1. Estimated range of the coverage area of base station (BS) of Automatic identification system (AIS) in the estuary of the Yana River

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