FEATURES OF PROPAGATION OF RADIO SIGNALS IN THE VLF RANGE DURING HIGH-ENERGY PROTON PRECISIONS IN HIGH LATITUDE REGION.

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The invasion of solar protons into the Earth's magnetosphere and their further precipitation into the ionosphere causes an increase in the total electron concentration in the F, E, D regions of the ionosphere, which leads to a change in the form of the vertical conductivity profile. Such events are divided according to the intensity of the flow of invading protons. The strongest are called GLE (Ground Level Enhancement) - in this case, the proton flux is recorded at the level of the Earth's surface. Such events are quite rare and 72 events have been registered so far. Weaker ones - SPE (Solar Particle Event) happen much more often and therefore do not have a serial number. Such events have a significant impact on the propagation of radio signals in the Earth-ionosphere waveguide, and therefore need to be studied. From the point of view of navigation, location and communication problems, it is necessary to evaluate the effect of proton intrusions of different intensities on the amplitude and phase of signals propagating in the Earth-ionosphere waveguide. On the other hand, from the point of view of the geophysical task of monitoring the state of the Earth-ionosphere waveguide, it is necessary to find out whether it is possible to determine the state of the waveguide from ground-based measurements of the amplitudes and phases of constantly acting signals of an anthropogenic nature in order to predict its radio permeability in a wide frequency range. Both tasks, forward and backward, are interconnected and require obtaining radio responses that are clean from extraneous interference during these events. To obtain such responses, it is necessary either to have a significant amount of ground-based measurements of radio signals at different stations for their further processing by statistical methods. An example of this approach is the Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortium (AARDDVARK) network. Another approach involves the widespread use of numerical methods both for modeling environmental conditions and for modeling the propagation of radio signals under the obtained conditions corresponding to specific geophysical conditions. This is the approach the authors used in this work.

Various events are considered, such as real GLE and SPE, synthetic electron density profiles and profiles built from EISCAT radar measurements in Tromso, Norway. To construct the profiles, the RUSCOSMICS, GDMI (Global Dynamic Model of Ionosphere) models developed by the PGI and IZMIRAN employees were used. International neutral atmosphere model NRLMSISE. International model of the earth's geomagnetic field IGRF. Modeling of electromagnetic signals was carried out by a numerical model of electromagnetic wave propagation developed at PGI. The signal of the model source was the sum of harmonic oscillations at the frequencies of the RSDN-20 long-range navigation radio system (11905, 12679, 14881 Hz).

The simulation results showed a strong and unambiguous dependence of the RSDN-20 signal amplitude on geophysical conditions and a less significant dependence of the signal phase.