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Hardware-software complex for determination of the Earth ionosphere parameters according to navigating systems

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Existing systems of distant short-wave communication provide the transfer of the information on long distances due to the reflection of radiowaves from the Earth ionosphere on the frequencies which do not exceed the critical frequency. To provide a sustainable functioning of such communication lines, first of all, it is required to know the highest frequency (maximum usable frequency - MUF) which can ensure at the reflection from the ionosphere the functioning of a radioline with higher reliability. With the help of common means of the short-wave band were conducted experimental studies on the use of a hardware-software complex for the problem-solving of the conditions' forecast for the radiowave propagation along the given line. The hardware-software complex includes a dual frequency navigating receiver working on GPS signals, and software solving a return problem of ionosphere radiotranslucence on the basis of the conjugate-gradient method.

The radio-translucence method is based on the transformation of normalized phase difference for radio waves. Mathematically, it corresponds to the transformation of integral equations of first kind. Implementation of this method involves measurement of radio signal parameters along the path "satellite – ground receiver" carried out at one station. The radio-translucence method allows the creation of altitude profiles of ionosphere electron content distribution with sampling of GPS signal registration. Realization of this method is based on the decision of a return ill-posed task of an ionosphere radio-translucence by the conjugate-gradient method. It is a mathematically strict method for the solution of inverse problems, with imposed restrictions enabling us to obtain admissible solutions on convex sets. This method steadily works at the task decision with restrictions and presence of local maxima.

The ill-posed nature of the problem of reconstructing electron content distribution using the results of radio-translucence does not allow us to obtain an exact solution for the main integral equation that would be stable under small variations in input data. In this case it is necessary to look for some approximate solution, choosing an acceptable solution from all the possible ones. Mathematical difficulties encountered when trying to apply this approach quite often force us to abandon the idea of obtaining a general solution to the problem of determining environmental parameter distribution. Most frequently, the problem is to be reduced to some elementary cases, for which acceptable results could be obtained.

Continuous observations of navigating satellites of systems Glonass and GPS allows to receive values of time variations, both a maximum of an ionosphere, and its high-altitude structure of electronic concentration of an ionosphere simultaneously on several azimuthal directions. The high-altitude structures of the ionosphere received as a result of inversion of satellite measurement data are presented on fig. 3. These structures are received for the nearest distances of a projection of subionospheric points from receiver depending on time on observation of satellites. The opportunity to restore a full high-altitude structure of distribution of electronic concentration of an ionosphere allows analyzing time variations practically any part of an ionosphere.

The restoration opportunity high-altitude structure of electronic concentration on observation on small time intervals allows to fix a big spatial the heterogeneity, observable in an ionosphere. Use of short time intervals of observation, sufficient for determination of a high-altitude structure of an ionosphere, allows localizing rather narrow areas of an ionosphere.

Simulation results and the high-altitude structures of electronic concentration restored on real GPS data are presented. The results of the experimental studies have shown according to this method a relative error of the MUF's definition no more than 5 % for day time and 11 % for night time observation. These results were obtained for Moscow region.