Propagation of ULF waves from virtual ionospheric sources generated by the SURA facility

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It is known that in the region of the ionosphere bounded from below by the conducting gyrotropic E-layer of the ionosphere (altitude 120 km) and from above by the region of a rapid decrease in the density of the ionospheric plasma, waveguide propagation along the Earth's surface of a fast magnetosonic wave (FMS) is possible. This region can be considered as a waveguide in which not only fast magnetosonic but also Alfven waves can propagate.

To analyze the nature of the propagation of ULF waves in an ionospheric waveguide from an ionospheric source, the ray method was used (see Kotik D.S. et al., Propagation of extremely low-frequency radiation from an artificial ionospheric source in a three-dimensional inhomogeneous magnetohydrodynamic waveguide // Izv. Vuzov. Radiophysics. 2021. V. 64, No. 1. pp. 1–11). The international models of the ionosphere (IRI-2016), atmosphere (MSIS-E-90) and geomagnetic field (DGRF/IGRF) were used when calculating ray trajectories. The calculations were carried out for the mid-latitude ionosphere. For definiteness, a point was chosen with the geographical coordinates of the SURA facility (56° N and 46° E). Two families of three-dimensional ray trajectories at the frequency f = 10 Hz are presented. The first one concerns the source associated with stationary current modulation in the E-layer for daytime conditions. The second one is for the source in the F-layer produced by ponderomotive forth for nighttime conditions. It is of interest to analyze the possibility of the output of ULFradiation from an ionospheric source to the Earth's surface; therefore, the main attention was paid to the output of trajectories to the heights of the lower ionosphere. At these heights, the ray approximation is inapplicable, and calculations of the radiation yield to the earth's surface must be carried out on the basis of the full wave approach. However, at these points, the observation of a signal on the Earth's surface is most likely. The results of such calculations should be taken into account when choosing the location of the receiving point when planning experiments to study the characteristics of artificial ULF signals generated in the ionosphere by the SURA facility.